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BIOLOGICAL SAMPLING ANALYSIS AND RESOURCES REPORT MARCH 1990

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REPORT

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Remedial Investigation and Feasibility Study
Feed Materials Production Center
Fernald, Ohio

Biological Sampling Analysis and Resources Report

Final

March 1990

Prepared by
Advanced Sciences, Inc.
International Technology Corporation

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BIOLOGICAL SAMPLING ANALYSIS AND RESOURCES REPORT

<u>Errata Sheet</u>

1. Page 4-12, column "Other." "<d.1.[g]" should read "<d.1.[f]."

2. Page 4-12, column "Other." "0.6[f]" should read "0.6[g]."

3. Page 4-17, eliminate "Lost in analysis."

4. Page 4-17, footnote b is "1988 samples."

5. Page 4-17, footnote c is "Onion leaves."

6. Page 4-17, footnote d is "Onion bulbs."

7. Page 4-17, second footnote e is footnote g.

8. Page 4-18, column "Other." "<1.4[g]" should read "<1.4[f]."

9. Page 4-18, column "Other." "<0.5[f]" should read "<0.5[g]."

10. Page 4-23, column "Grass Leaves," Site 4. "0.14" should read "0.41."

11. Page 4-23, column "Forb Roots," Site 28. "1.31" should read "0.31."

12. Page 4-28, column "U-238," Sample "Small mammal (Composite)." "0.6" should read "8.6."

13. Page 4-33, column "Sum of U Activity." "6.4" should read "2.7."

14. Page 4-34, column "Cs-137," Sample "White sucker," Site "PR-2." "0.2" should read "<0.2."

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

LIST OF TABLES

LIST OF TABLES
(Continued)

LIST OF FIGURES

LIST OF ACRONYMS

CERCLA	COMPREHENSIVE RESPONSE, COMPENSATION, AND LIABILITY ACT
CNC	CINCINNATI NATURE CENTER
DOE	UNITED STATES DEPARTMENT OF ENERGY
EPA	UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
FFCA	FEDERAL FACILITY COMPLIANCE AGREEMENT
FMPC	FEED MATERIALS PRODUCTION CENTER
FS	FEASIBILITY STUDY
IT	IT CORPORATION
NCRP	NATIONAL COUNCIL ON RADIATION PROTECTION
NEPA	NATIONAL ENVIRONMENTAL POLICY ACT
NLO	NATIONAL LEAD COMPANY OF OHIO
NRC	NUCLEAR REGULATORY COMMISSION
OASS	OHIO AGRICULTURAL STATISTICS SERVICE
ODNR	OHIO DEPARTMENT OF NATURAL RESOURCES
OEPA	OHIO ENVIRONMENTAL PROTECTION AGENCY
RI	REMEDIAL INVESTIGATION
WMCO	WESTINGHOUSE MATERIALS COMPANY OF OHIO

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PROJECT FILES, TASK 3.5

EXECUTIVE SUMMARY

FEED MATERIALS PRODUCTION CENTER OPERATIONS

The Feed Materials Production Center (FMPC) is a government-owned, contractor-operated federal facility for the production of pure uranium metals for the United States Department of Energy (DOE). The principal operations consist of metal fabrication and processing of accumulated plant residues and miscellaneous feed materials obtained from other DOE sites. The Westinghouse Materials Company of Ohio (WMCO) is the current operating contractor.

Both radioactive and nonradioactive wastes are generated as a result of plant operations. Until 1984, long term storage of solid and slurried wastes at the FMPC occurred in on-site pits, landfills, silos, and drums. Currently, wastes are drummed and stored for off-site disposal. Liquid effluent and airborne discharges are also generated as a result of plant operations. Slightly radioactive particulates are ventilated through highly efficient bag-type dust collectors. General operations, however, have resulted in releases of uranium to the atmosphere since 1952. Liquid effluent from the production process is sent to a general plant sump for treatment prior to release to the Great Miami River. Untreated storm water runoff from the process areas is also routinely discharged to the Great Miami River and periodically to Paddy's Run.

FEDERAL FACILITY COMPLIANCE AGREEMENT AND RI/FS

On March 9, 1985, the United States Environmental Protection Agency (EPA) issued a Notice of Noncompliance letter to DOE identifying major concerns over potential environmental impacts associated with the FMPC's past and present operations. On July 18, 1986, a Federal Facility Compliance Agreement (FFCA) was jointly signed by

DOE and EPA pertaining to environmental impacts associated with the FMPC. The FFCA was entered into pursuant to Executive Order 12088 (42 CFR 47707) to ensure compliance with existing environmental statutes and implementing regulations. In response, a site-wide Remedial Investigation/Feasibility Study (RI/FS) is being conducted pursuant to the Comprehensive Response, Compensation, and Liability Act (CERCLA) and in conformance with EPA guidance. The RI/FS also will be consistent with the guidelines and criteria and considerations set forth in the National Contingency Plan (40 CFR 300), and the Superfund Amendment Reauthorization Act of 1986.

The purpose of the RI is to determine the nature and extent of any release, or threat thereof, of hazardous or radioactive substances, pollutants, or contaminants, and to gather all necessary data to support the FS. The purpose of the FS is to develop, evaluate, and recommend remedial action alternatives to protect public health and welfare and the environment from releases or threatened releases of hazardous or radioactive substances, pollutants, or contaminants from the FMPC. The principal controlling document for the RI/FS is the RI/FS Work Plan (Revision 3) approved by the EPA in March 1988, which includes a Biological Resources Sampling Plan. This plan was formulated and carried out with the following objectives:

- To determine if any radiological or hazardous substance release to the FMPC environs has resulted in significant uptake, assimilation, and transfer through ecological habitats, including surface water, sediments and adjacent wetlands;
- To determine if any radiological or hazardous substance release to the FMPC environs has resulted in uptake and assimilation in terrestrial vegetation, agricultural produce, and forage crops;
- To determine if the above processes represent significant pathways to human receptors; and

- To determine if federal or state threatened or endangered species exist within the FMPC environs, and the potential risk posed to their existence or welfare through contaminant release from the FMPC.

This study will provide a key informational source for the RI/FS and will be used to support the evaluation of environmental impacts of remedial actions pursuant to National Environmental Policy Act (NEPA) requirements.

BACKGROUND OF THE BIOLOGICAL RESOURCES STUDY

The biology and ecology of the FMPC have been extensively characterized by Facemire et al. (1990) in studies conducted in 1986 and 1987. They defined a number of distinct habitats on the FMPC, including riparian woodlands (the Great Miami River, Paddy's Run and adjacent wetlands), deciduous woodlands, pine plantations, grazed and ungrazed pastures, and a reclaimed fly ash pile. These habitats are estimated to contain 47 species of trees and shrubs, 190 species of herbaceous plants, 8 mammal species, 98 bird species, 10 species of amphibians and reptiles, 21 species of fish, 47 families of aquatic macroinvertebrates, and 132 families of terrestrial invertebrates.

The present biological resources study, conducted in 1987 and 1988, focused on potential exposure of humans or wildlife to radionuclides and other hazardous substances by transfer through the food chain. Possible pathways include aquatic food chains, for example, sediments to invertebrates to fish to terrestrial animals, including humans, and terrestrial food chains, from soils to vegetation to animals. For terrestrial resources, radionuclide concentrations were determined in soils, forage grasses, and agricultural produce. Several samples for radionuclide analysis were also obtained from small mammals and one deer. Radionuclide concentrations were also determined in aquatic plants, benthic macroinvertebrates, and fish in the Great Miami River, Paddy's Run, and adjacent wetlands. These data were compared to similar data collected in recent years by WMCO. A subsample of biological resources samples was analyzed for priority pollutants, pesticides, PCBs, and metals.

Additionally, acute and chronic toxicity tests were conducted on the FMPC effluent entering the Great Miami River. Only the initial results of this last study, which is still in progress, are presented in this report. Finally, habitat and population surveys of the Indiana bat (Myotis sodalis), a Federally endangered species occurring in Hamilton and Butler counties, and the cave salamander (Eurycea lucifuga), listed as threatened in Ohio, were conducted to estimate the potential impact of FMPC contaminants on these species.

RESULTS AND DISCUSSION

Total uranium concentrations in produce from a control area in Brookville, Indiana, upwind from the FMPC, ranged from below detection limits to 4.1 pCi/g. Uranium concentrations in locally grown produce from gardens and a roadside stand were similar, below detection limits to 4.8 pCi/g, indicating that produce consumption is probably not a significant pathway for human exposure to FMPC-derived uranium. Levels of other radionuclides in produce were typically near or below detection limits, indicating that human exposure to these substances as a result of FMPC releases is insignificant.

Total uranium in soil and vegetation collected from the FMPC ranged from below detection limits to 35.6 pCi/g, with leaves typically having lower concentrations than roots. Uranium concentrations in soil and vegetation tended to be higher to the north and east of the FMPC, which correlates with the direction of prevailing winds and suggests an atmospheric pathway for radionuclide transport to these areas. Uranium concentrations in soil and vegetation exhibited high spatial variability, but concentration ratios (plant:soil) in forage plants were always less than 1, indicating that plants on the FMPC are not concentrating uranium at levels higher than those in soil.

Data on radionuclide transfer to terrestrial wildlife species on the FMPC are very limited. Total uranium in the one small mammal sample in this study was 18 pCi/g (in a composite sample of mouse and shrew organs near Waste Pit No. 5), which could indicate a possible exposure pathway to raptorial birds, e.g. hawks, feeding on the FMPC. However, the wide feeding ranges of these birds would limit their exposure to radionuclides from the FMPC. Uranium concentrations in doves and quail, a potential exposure pathway for human beings, have not yet been determined. Radionuclides in the one deer sample obtained on the FMPC were below detection limits.

Aquatic organisms could be exposed to FMPC-derived radionuclides in wetlands, in Paddy's Run, and in the Great Miami River. Fish from these habitats are in turn a potential pathway for transport of radionuclides to wildlife and humans. Detectable levels of uranium were found in soil (16.3 pCi/g) and grass and cattails (1.4 to 31.3 pCi/g) from a wetland site on the east side of Paddy's Run on the FMPC. Uranium was also found in macroinvertebrates (1.5 to 6.4 pCi/g) and fish (0.6 to 3.7 pCi/g) from Paddy's Run. In the Great Miami River, uranium concentrations in macroinvertebrates ranged from a detection limit of 0.6 pCi/g to 6.5 pCi/g, and were below detection limits in fish. These data indicate that fish, birds, and mammals feeding on macroinvertebrates and fish may be exposed to uranium through the aquatic food chain on the FMPC, but the data are too limited to quantify radionuclide transport through the aquatic food chain. A study of the potential for bioaccumulation of uranium by fish in Paddy's Run and the Great Miami River, which is being conducted in 1990 as part of RI/FS testing, will address this question in detail.

Approximately 8% of all biological samples collected for radionuclide analysis were also tested for priority (organic) pollutants, PCBs, pesticides, and heavy metals. Priority pollutants, PCBs, and pesticides were below detection limits in all samples tested, and heavy metal concentrations were low relative to potentially toxic levels. On the basis of these data, releases of hazardous substances other than radionuclides from the FMPC through biological pathways do not appear to be a threat to wildlife or to human beings.

Toxicity testing of FMPC effluent showed no acute toxicity. In chronic tests, growth of the alga Selanastrum capricornutum was inhibited by 33% at an effluent concentration of 12.5%, and reproduction by the invertebrate Ceriodaphnia dubia was reduced by 32% at an effluent concentration of 25%. These effluent concentrations, however, are at least forty times higher than the concentration of FMPC effluent once it enters the Great Miami River, even at extreme low river flow of 280 ft^3/s. Toxicity testing of FMPC effluent is continuing into 1990. In addition, tests will be conducted in 1990 to determine whether contaminants leachable from soils and sediments on the FMPC could be toxic to aquatic organisms.

Potential habitat for the cave salamander and the Indiana bat exists on and adjacent to the FMPC, and Indiana bats were netted approximately 3.5 miles east of the northeast boundary of the FMPC. However, neither cave salamanders nor Indiana bats have been positively identified on the FMPC itself, and Facemire et al. (1990) found no Federally endangered species on the FMPC. There is no evidence to date that contaminants from the FMPC have any effect on threatened or endangered species listed by Federal or State of Ohio authorities.

REFERENCE

Facemire, C.F., S.I. Guttman, D.R. Osborne, and R.H. Sperger. 1990. Biological and Ecological Site Characterization of the Feed Materials Production Center. Prepared for Feed Materials Production Center. Westinghouse Materials Company of Ohio.

1.0 INTRODUCTION

1.1 PROJECT SETTING

The Feed Materials Production Center (FMPC) is a government-owned, contractor-operated federal facility for the production of pure uranium metals for the United States Department of Energy (DOE). The facility is located on a 1,050 acre site in a rural area about 20 miles northwest of downtown Cincinnati, Ohio in portions of Hamilton and Butler counties (Figure 1-1). The villages of Fernald, Ross, New Baltimore, and Shandon are within a few miles of the site. The production facilities occupy about 136 acres near the center of the site.

Topographically, the facilities rest on a relatively level plain about 580 feet above sea level. The main drainage channel for the western portion of the site is Paddy's Run, a tributary of the Great Miami River. Paddy's Run originates just north of the FMPC and flows southward. For a part of the year it is a dry stream bed with only occasional flows. Drainage from the site is to the Great Miami River which lies about three-quarters of a mile to the east. Vegetative cover of the site includes deciduous forests, grasslands and cropland. Surrounding land use includes several residences and small industries; however, the major economic activities in the area are farming and dairy operations.

Within 50 miles of the FMPC, there is a population of approximately 2,577,000. Hamilton County has a population of about 864,000 and Butler County a population of about 275,000 people (NLO 1985). Most populated areas in the vicinity of the FMPC are unincorporated small towns varying from an estimated population of 30 at Fernald to 3,000 at Ross. Table 1-1 identifies population by sector within a five-mile radius of the FMPC. Table 1-2 shows the population for the towns within this radius.

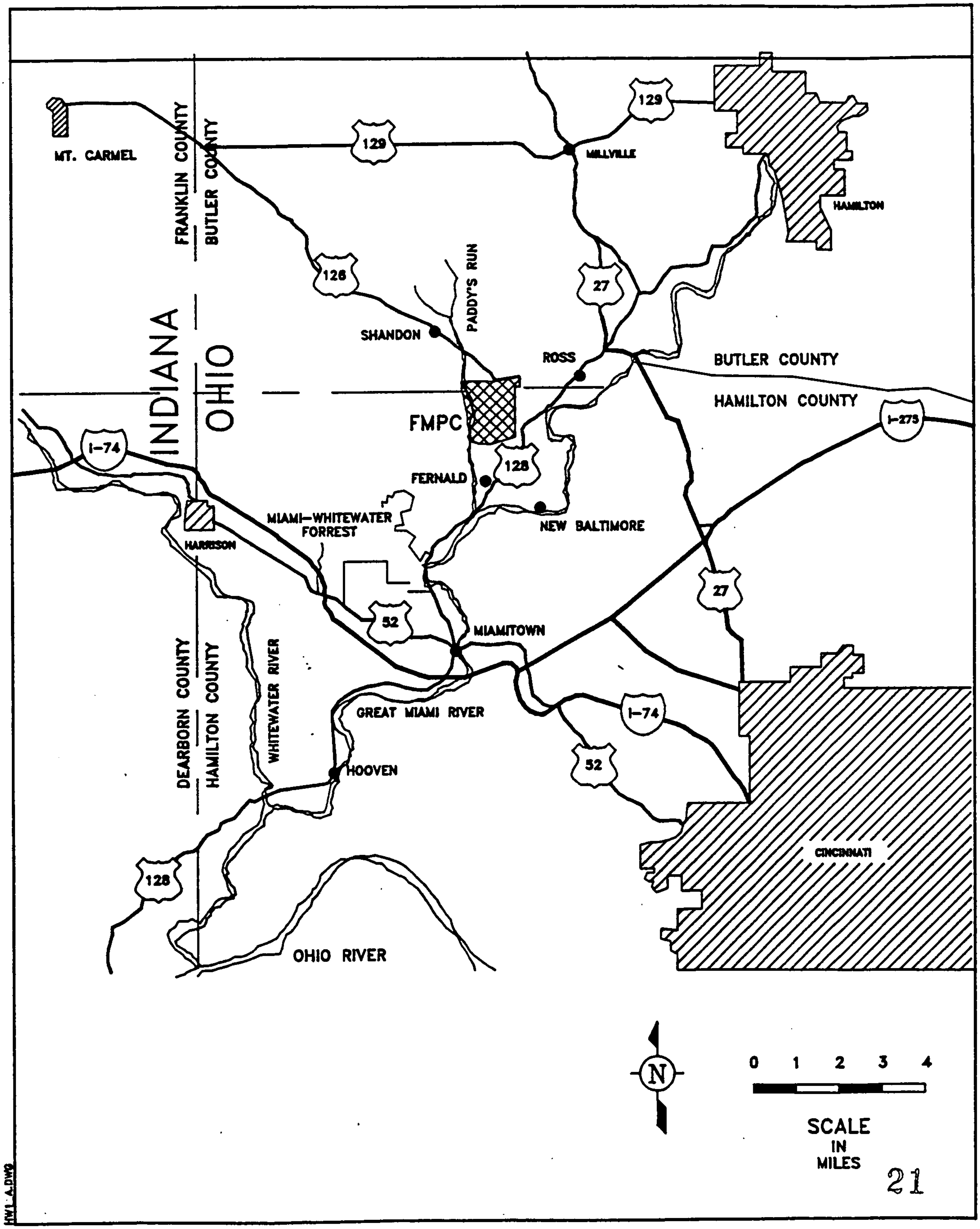


FIGURE 1-1. REGIONAL LOCATION OF THE FEED MATERIALS PRODUCTION CENTER

TABLE 1-1

POPULATION ESTIMATES BY SECTOR WITHIN A FIVE-MILE RADIUS OF THE FMPC

Miles From FMPC	Direction																Distance Totals
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
0-1	13	3	6	3	0	6	6	0	10	16	6	3	0	3	0	13	88
1-2	13	10	323	134	19	3	493	13	38	42	48	6	10	10	22	29	1,213
2-3	102	90	58	2,224	26	118	176	358	58	134	54	38	16	19	294	86	3,851
3-4	45	54	61	112	243	218	214	262	192	118	58	669	192	61	102	141	2,742
4-5	272	64	41	16	224	368	717	352	371	80	19	224	301	64	93	250	3,456
TOTAL	445	221	489	2,489	512	713	1,606	985	669	390	185	940	519	157	511	519	11,350

Source: Dames and Moore n.d.

TABLE 1-2

POPULATION CENTERS WITHIN A FIVE-MILE RADIUS OF THE FMPC

Population Center	Approximate Distance in Miles		Estimated Population
Fernald	1.75		30
Shandon	2.00		200
Venice (Ross)	2.50		3,000
New Baltimore	2.75		200
New Haven	3.00		200
Dunlap	4.00		100
Harrison	5.00		4,408
		TOTAL	8,138

Source: NLO (1977)

1.2 FMPC OPERATIONS

The principal operations at the FMPC consist of metal fabrication and processing of accumulated plant residues and miscellaneous feed materials obtained from other DOE sites. A small amount of thorium processing has been conducted in the past and thorium is stored on site. The Westinghouse Materials Company of Ohio (WMCO) is the current operating contractor.

As a result of the activities conducted at the facility, both radioactive and non-radioactive wastes are generated. Until 1984, long term storage of solid and slurried wastes at the FMPC occurred in onsite pits, landfills, silos, and drums. Nothing has been placed in the pits since 1985 and in the silos since the 1950's. Currently, wastes are drummed and stored for offsite disposal.

Liquid effluent and airborne discharges are generated as a result of plant operations. Slightly radioactive particulates generated by manufacturing processes at the FMPC are ventilated through highly efficient bag-type dust collectors. General operations, however, including collector failures, have resulted in releases of uranium to the atmosphere since 1952. Liquid effluent from the production process is sent to a general plant sump for treatment prior to release to the Great Miami River. Untreated stormwater runoff from the process areas is also routinely discharged to the Great Miami River and periodically to Paddy's Run. Because of the permeable nature of the underlying sand and gravel aquifer, there is a potential for uranium to migrate into the groundwater.

1.3 FEDERAL FACILITY COMPLIANCE AGREEMENT AND RI/FS

On March 9, 1985, the United States Environmental Protection Agency (EPA) issued a Notice of Noncompliance letter to DOE identifying major concerns over potential environmental impacts associated with the FMPC's past and present operations. Between April 1985 and July 1986, conferences were held between DOE and EPA representatives to discuss the issues and steps proposed by DOE to achieve and maintain compliance.

On July 18, 1986, a Federal Facility Compliance Agreement (FFCA) was jointly signed by DOE and EPA pertaining to environmental impacts associated with the FMPC. The FFCA was entered into pursuant to Executive Order 12088 (42 CFR 47707) to ensure compliance with existing environmental statutes and implementing regulations. In particular, the FFCA was intended to ensure that environmental impacts associated with past and present activities at the FMPC are thoroughly investigated so that appropriate remedial response actions can be formulated, assessed, and implemented. In response, a sitewide Remedial Investigation/ Feasibility Study (RI/FS) is being conducted pursuant to the Comprehensive Response, Compensation, and Liability Act (CERCLA) and in conformance with the EPA "Guidance on Remedial Investigations Under CERCLA" (EPA 1985a) and the EPA "Guidance on Feasibility Studies Under CERCLA" (EPA 1985b). The RI/FS will also be consistent with the guidelines and criteria and considerations set forth in the National Contingency Plan (40 CFR 300), and the Superfund Amendment Reauthorization Act of 1986.

Within the CERCLA framework, the purpose of the RI is to determine the nature and extent of any release, or threat thereof, of hazardous or radioactive substances, pollutants, or contaminants, and to gather all necessary data to support the FS. The RI at the FMPC is being conducted to satisfy the following specific objectives:

- Identify and characterize the sources of radiological and chemical contamination;
- Determine the nature and extent of radiological and chemical components in air, soils, sediments, surface water, and ground water media, and characterize their occurrence in aquatic and terrestrial organisms both on and off site;

- Identify the pathways and mechanisms for radiological and chemical constituent migration, and conduct public health risk assessments and environmental impact studies;

- Develop, validate, and apply various site models in order to augment the current understanding of the site environment, and to predict future impacts with and without remedial actions in lieu of future observations; and,

- Provide necessary information for the identification, evaluation, and selection of the most environmentally and economically acceptable alternatives in the FS.

The purpose of the FS is to develop, evaluate, and recommend remedial action alternatives to protect public health and welfare and the environment from releases or threatened releases of hazardous or radioactive substances, pollutants, or contaminants from the FMPC.

The principal controlling document for the RI/FS is the RI/FS Work Plan (Revision 3) approved by the EPA in March 1988, including the supporting Sampling Plan, Quality Assurance Project Plan, and Health and Safety Plan. Subsequent to Work Plan approval, the DOE and EPA agreed to separate the FMPC into five operable units and to prepare individual RI and FS reports for each operable unit. These operable units are described in detail in Appendix A.

Operable Unit 5, termed "Environmental Media," includes the regional ground water, surface water, sediments, soils, air, and flora and fauna resources potentially affected by the FMPC. The biological resources study reported here was conducted as part of the sitewide RI, following EPA guidance (EPA 1985a), in accordance with the Biological Resources section of the Sampling Plan. This study will provide a key informational source for the RI/FS for Operable Unit 5, including the associated risk assessment. In addition, this information will be used to support the evaluation of environmental impacts pursuant to the National Environmental

Policy Act (NEPA) requirements for each operable unit. The four specific objectives of the Biological Resources Sampling Plan were:

- To determine if any radiological or hazardous substance release to the FMPC environs has resulted in significant uptake, assimilation, and transfer through ecological habitats, including surface water, sediments, and adjacent wetlands;

- To determine if any radiological or hazardous substance release to the FMPC environs has resulted in uptake and assimilation in terrestrial vegetation, agricultural produce, and crops;

- To determine if the above represent significant pathways to human receptors; and

- To determine if federal or state threatened or endangered species exist within the FMPC environs, and the potential risk which is posed to their existence or welfare through contaminant release from the FMPC.

2.0 EXISTING BIOTIC ENVIRONMENT

This chapter presents a characterization of the biological resources in the FMPC vicinity. Following a description of agriculture in the vicinity are sections on the flora and fauna of the FMPC. These latter sections are drawn from the report by Facemire et al. (1990), where not specifically stated otherwise. Information is also presented concerning the rare, threatened, and endangered species that occur in this area of southern Ohio.

2.1 AGRICULTURE

Hamilton and Butler counties, within which the FMPC lies, are highly urbanized. However, areas immediately surrounding the FMPC are primarily rural in nature, supporting small farms. The average farm size for both counties varies from 107 to 150 acres. Crops grown include soybeans, corn, fruits, vegetables, and alfalfa and grasses for harvest as hay. Pasture vegetation is dominated by grasses. Fence rows and associated vegetation provide boundaries for many of the agricultural fields in the region.

The soil fertility in the Great Miami River Valley is some of the highest in Ohio. Rented FMPC land located on the first level of Great Miami River terraces produces 175-180 bu/acre of corn, while the average for the area is 115-120 bu/acre (Davis 1987).

Most of the farms in the vicinity of the FMPC market their annual production. Corn and soybeans are stored and sold for feed and processing. In 1986 Butler County had 4,129,000 bushels of off-farm commercial grain storage capacity and Hamilton County had 12,409,000 bushels of capacity. Most of the hay, however, is consumed on the farm where it is grown. Table 2-1 lists 1986 agricultural statistics for Hamilton and Butler counties as well as the Ohio average production for each crop reported.

TABLE 2-1

1986 AGRICULTURAL STATISTICS FOR HAMILTON AND BUTLER COUNTIES AND OHIO[a]

Commodity	Butler Co. (Avg.)	Hamilton Co. (Avg.)	Ohio (Avg.)
Average farm size, acres	150.00	107.00	180.00
Corn, for grain (bushels per acre)	110.60	121.20	128.00
Soybeans (bushels per acre)	37.70	41.20	41.00
Wheat (bushels per acre)	39.80	---	46.00
Hay (tons per acre)	2.61	3.05	2.95

[a] Source: OASS (1986)

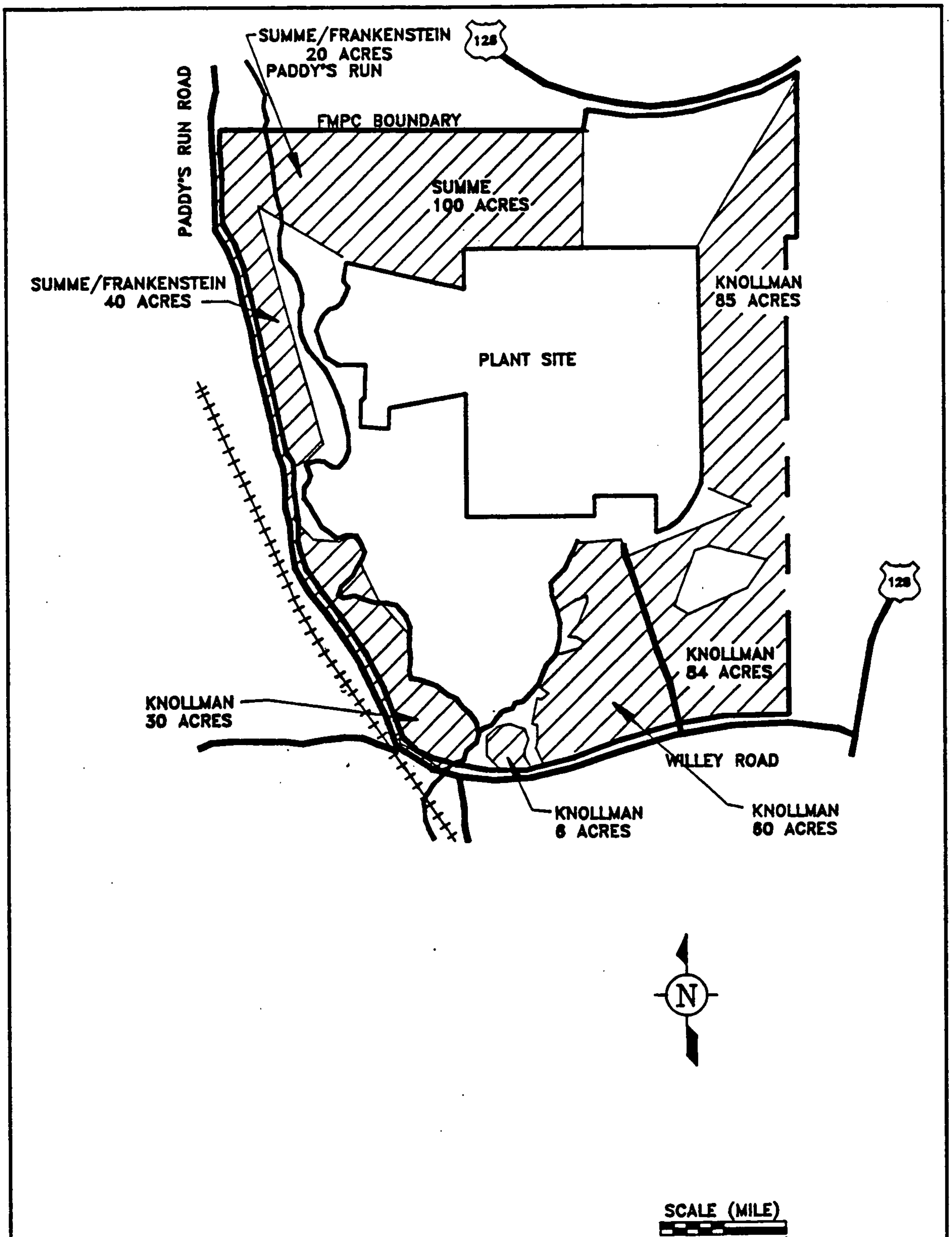
Livestock production near the FMPC consists primarily of dairy and beef cattle. There are three dairy operations within two miles of the FMPC. Dairy and beef cattle have grazed for over 30 years on land within the confines of the FMPC. However, only dairy cattle are currently grazed on FMPC property, on 425 acres of licensed allotments (Figure 2-1). Beef from local cattle is used for personal consumption by local farmers and distributed regionally by a local slaughterhouse. Generally, grazing leases on FMPC lands are in force for 30-40 years (Davis 1987). Milk produced from the site dairies is marketed and sold through regional commercial processors and vendors (Davis 1987).

The rural nature of the area around the FMPC has attracted many people who work in metropolitan Cincinnati, but prefer a rural residence on 1 to 2 acres, as well as those who maintain "hobby" farms of 5-10 acres (Bartels 1986). A variety of vegetables and fruit is grown in small plots at these residences, including cabbage, collards, lettuce, beets, pinto beans, sweet corn, squash, tomatoes, and pumpkins. The majority of the fruits and vegetables is consumed by the growers.

Within one mile of the FMPC are several roadside stands selling a variety of produce (Davis 1987). Agricultural statistics are not compiled on backyard gardens or small producers who do not market in volume.

2.2 TERRESTRIAL ORGANISMS

Terrestrial organisms include the plants that grow in areas potentially affected by the FMPC, animals that use habitats on the site, and the agricultural crops and livestock described above. This section summarizes the studies to date that characterize the terrestrial environment of the FMPC and vicinity. Generally these studies present location, species composition, density, and



31

FIGURE 2-1. GRAZING AREAS ON FMPC PROPERTY

relative abundance data, and provide habitat analyses as appropriate. A generalized flow diagram (Figure 2-2) illustrates potential pathways for exposure of humans to FMPC contaminants through terrestrial organisms.

2.2.1 Flora

The FMPC was established in an area dominated by native forest, pasture and cropland, and lies in the Eastern Deciduous Forest Province Oak-Hickory Forest Section, as presented in Bailey (1978). Historically, this temperate deciduous forest was dominated by tall, broadleaf trees, providing a continuous and dense summer canopy, with the leaves shedding completely in winter. Nearly all of the indigenous stands of forest in southwestern Ohio have been cleared, cut, or altered for agriculture or urban development, and the FMPC area is characteristic of these land use practices.

The vegetative communities occurring on the FMPC are typical of southwestern Ohio. Land use outside the Production Area and waste storage areas is predominantly agricultural, resulting in a landscape dissected by open pasture, with forests occupying drainages or used as natural fencerows or hedges. The understory is often grazed or altered by clearing or selective cutting. Plant communities identified on the FMPC include a reclaimed fly ash pile (RFAP), introduced grasslands (IG), areas planted in pine trees (P), deciduous woodland (W), and riparian woodlands (R) (Figure 2-3).

The reclaimed fly ash pile supports an introduced community colonized by immature American elm (Ulmus americana), eastern cottonwood (Populus deltoides), black locust (Robinia pseudoacacia), redbud (Cercis canadensis), and boxelder (Acer negundo) (Tables 2-2 and 2-3). Herbaceous species present are fescue (Festuca sp.), Kentucky bluegrass (Poa pratensis), and

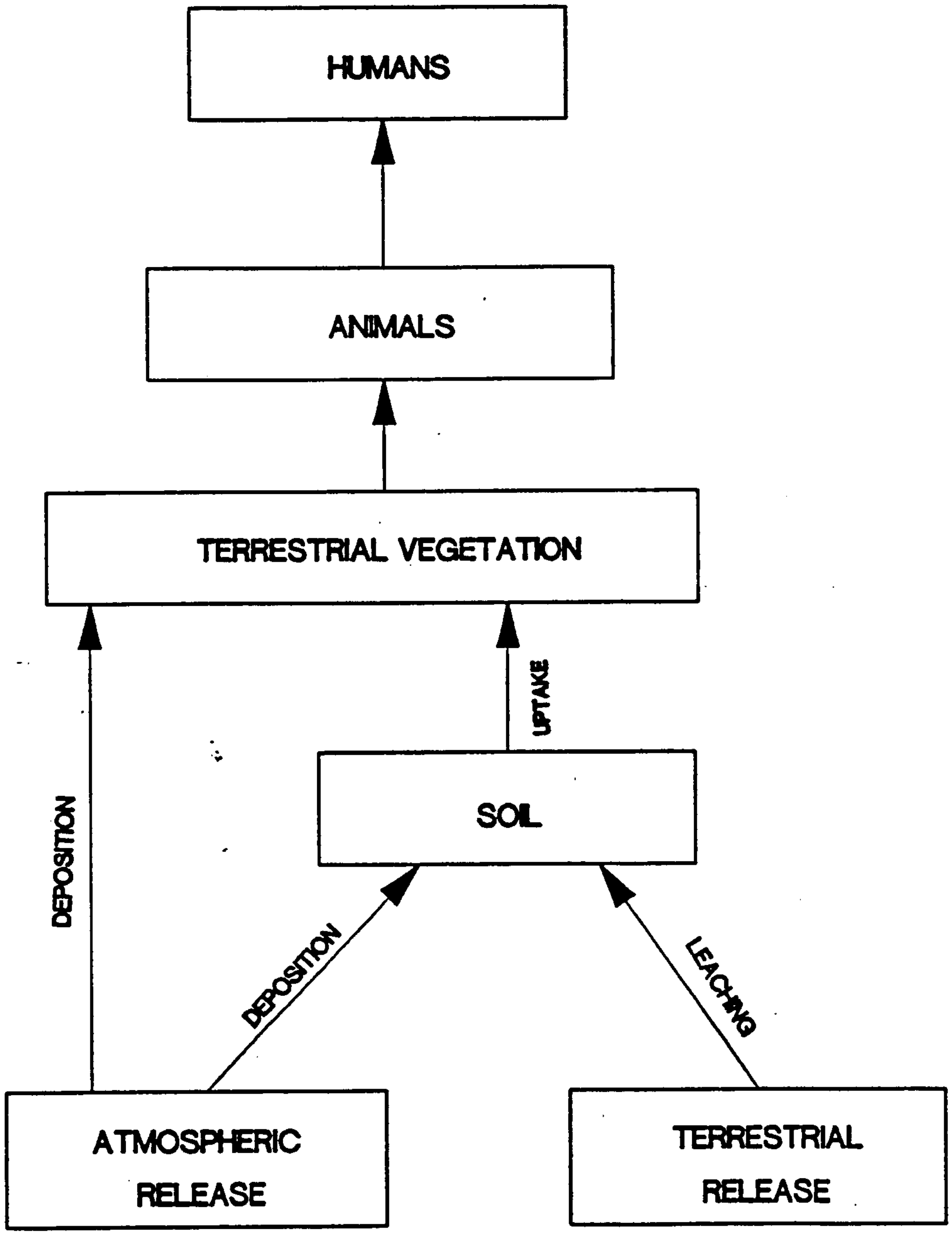


FIGURE 2-2. GENERALIZED TERRESTRIAL FOOD WEB AND FLOW DIAGRAM OF POTENTIAL CONTAMINANT UPTAKE BY HUMANS

33

HEB'24

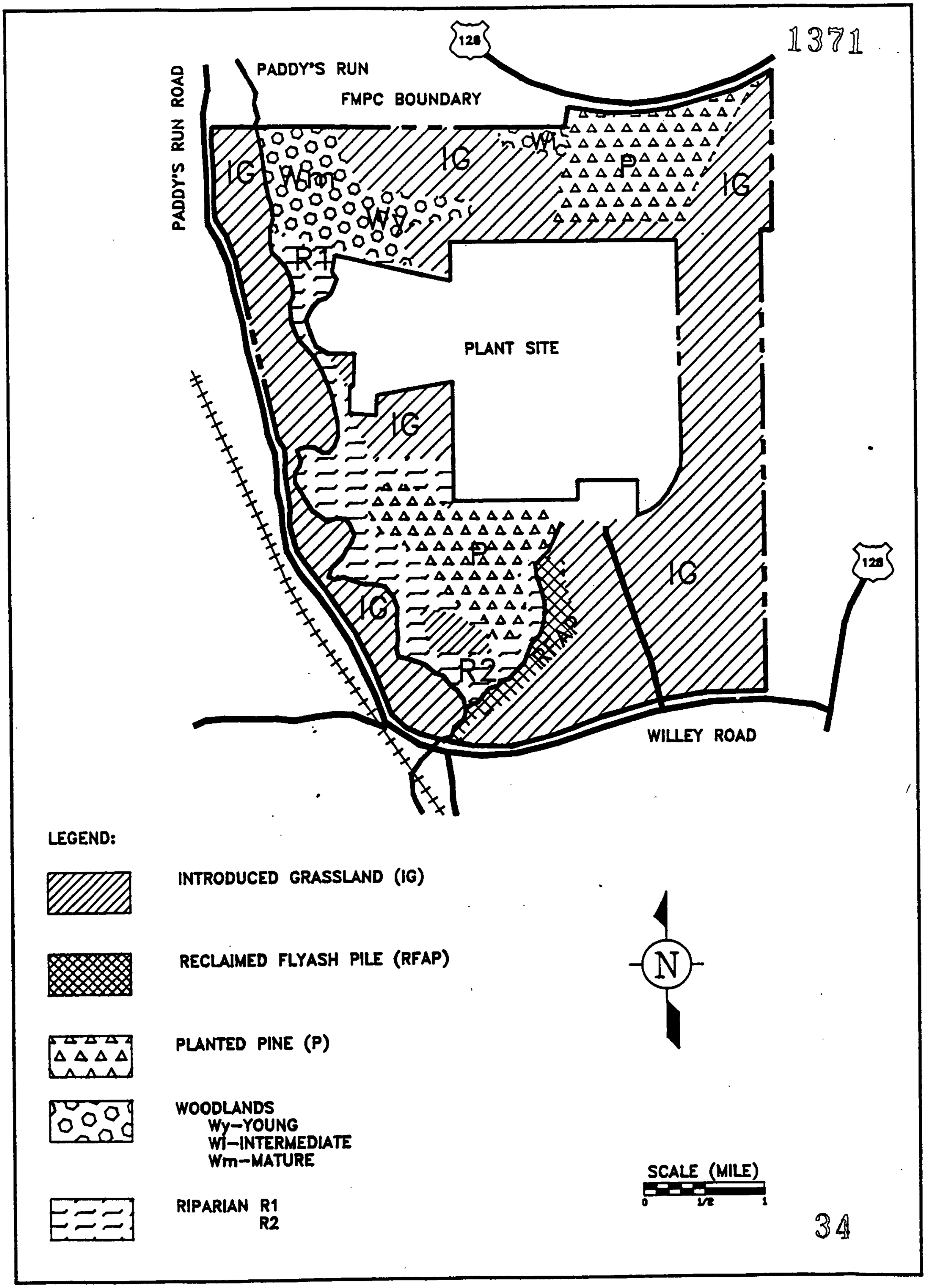


FIGURE 2-3. VEGETATION TYPES PRESENT ON THE FMPC

TABLE 2-2

PERCENT FREQUENCY OF TREES IN THE WOODED HABITATS OF THE FMPC

			WOODLAND			RIPARIAN	
SPECIES	P[a]	RFAP[b]	W1 Intermediate	W2 Young	W3 Mature	R1	R2
White pine	57	0	0	0	0	0	0
Austrian pine	50	0	0	0	0	0	0
Norway spruce	1	0	0	0	0	0	0
Eastern red cedar	0	0	33	0	0	0	0
Black willow	0	0	0	0	0	17	0
Eastern cottonwood	0	50	17	0	0	83	17
Black walnut	0	0	17	0	50	50	67
Shellbark hickory	0	0	83	0	0	0	0
Shagbark hickory	0	0	0	0	0	17	0
Bitternut hickory	0	0	0	0	17	33	0
Mockernut hickory	0	0	33	0	17	0	0
Chestnut oak	0	0	33	0	17	0	0
Chinquapin oak	0	0	0	0	0	17	0
Northern red oak	0	0	50	0	17	0	0
Shingle oak	0	0	50	0	0	17	0
Swamp white oak	0	0	0	0	0	0	17
American elm	0	75	83	83	100	50	100
Slippery elm	0	0	17	0	67	50	50
Hackberry	0	0	67	17	33	67	67
Osage-orange	0	0	0	0	0	33	0
American sycamore	0	0	0	33	0	50	33
Black cherry	0	0	67	33	17	17	0
Hawthorn	0	0	0	0	0	33	0
Redbud	0	25	0	0	0	0	0
Kentucky coffee tree	0	0	0	0	17	0	0
Honey locust	0	0	17	0	0	50	17
Black locust	0	25	17	0	0	0	0
Sugar maple	0	0	0	17	67	17	0
Red maple	0	0	0	17	0	0	0
Silver maple	0	0	17	17	0	0	17
Boxelder	0	25	17	50	50	67	100
Ohio buckeye	0	0	0	0	50	0	33
Common persimmon	0	0	17	0	0	0	0
White ash	0	0	33	100	33	17	17

Source: Facemire et al. (1990).

[a] Pine Plantation

[b] Reclaimed Fly Ash Pile

TABLE 2-3

PERCENT FREQUENCY OF SHRUBS IN DECIDUOUS HABITATS OF THE FMPC

		Woodland			Riparian	
SPECIES	RFAP[a]	W1 Intermediate	W2 Young	W3 Mature	R1	R2
Sawbrier	0	0	0	0	17	17
Black walnut	0	17	0	17	50	0
Bitternut hickory	0	0	0	33	17	17
Shellbark hickory	0	50	0	0	0	0
Chestnut oak	0	0	0	17	0	0
Swampwhite oak	0	0	0	0	17	17
American elm	0	17	50	17	33	33
Slippery elm	0	17	0	17	17	0
Hackberry	17	17	0	17	50	17
Black cherry	17	17	33	17	17	0
Hawthorn	0	0	0	0	17	0
Multiflora rose	0	83	67	0	17	0
Prairie rose	17	0	0	0	0	0
Blackberry	0	50	17	0	17	0
Burning bush	17	0	0	0	17	17
Poison ivy	50	33	17	50	17	17
Sugar maple	0	17	0	67	17	0
Silver maple	0	0	17	0	0	0
Black maple	0	0	0	0	0	17
Boxelder	33	17	50	0	50	50
Ohio buckeye	0	0	50	0	50	50
Grape vine	0	33	50	33	33	33
Virginia creeper	0	17	17	33	17	17
Roughleaf dogwood	0	67	50	17	17	0
White ash	0	50	0	17	33	33
Trumpet creeper	0	50	0	0	17	0
Honeysuckle	17	83	17	0	17	17

Source: Facemire et al. (1990)

[a] Reclaimed Fly Ash Pile

orchard grass (Dactylis glomerata). This site is periodically disturbed by various FMPC operations.

The introduced grassland communities are characterized by the presence of old field vegetation. Characteristic species include timothy (Phleum pratense), red top (Agrostis sp.), Kentucky bluegrass, and the early successional herbaceous species teasel (Dipsacus sylvestris), ragweed (Ambrosia sp.), moth mullein (Verbascum blatteria), and wild parsnip (Pastinaca sativa).

Approximately 200 acres of the grassland are currently used as pasture for dairy cattle, and an area of mown grass is maintained between the woodland adjacent to Paddy's Run and the planted conifers and between rows of conifers to reduce the fire hazard. The dominant herbaceous species of this area consist of many introduced grasses. Species present are red fescue (Festuca rubra) and other fescue species, Kentucky bluegrass and other bluegrass species, and orchard grass. Other dominant or common species of the grassland area include brome grass (Bromus sp.), redtop (Agrostis stolinferous var. major), timothy, chickweed (Stellaria media), buttercup (Ranunculus sp.), winter cress (Barbarea vulgaris), red and white clover (Trifolium pratense and T. repens), ironweed (Vernonia sp.), thistle (Cirsium sp.), yarrow (Achillea millefolium), and goldenrod (Solidago sp.). Appendix B provides more detail on the observed plant species.

The grassland habitats are continually affected by mowing, grazing, and bush hogging. These practices provide a controlling influence on the regeneration of these areas, and in addition to the agricultural uses, account for the predominance of introduced grasses (Appendix B).

The pine woodlands were planted in 1972. Species planted were white pine (Pinus strobus), Austrian pine (Pinus nigra), and Norway spruce (Picea excelsa). White pine is the dominant species present, both by frequency (Table 2-2) and by percent cover (Facemire et al. 1990). (Frequency is the percent of sampling locations in which a species occurs. Percent cover is the percent of ground area shaded by foliage of a species.) Norway spruce occurs only occasionally (Table 2-2). Dominant herbaceous species in the pine woodlands include red fescue, brome grass, Kentucky bluegrass, and goldenrod.

Native woodland vegetation on the FMPC is in various successional stages related to the intensity and frequency of disturbance in these areas. Disturbance to the understory is caused by cattle grazing and bush hogging. This affects the extent of native forest species regeneration, which in turn affects the composition and structure of the woodlands. The woodland habitat can be distinguished into three stands based upon species composition and level of disturbance, which also gives some indication of stand maturity. Fragmentation of a once continuous woodland causes differences in the dominant species present. Each woodland area is composed of species characteristic of the mixed floodplain forest community type, following criteria presented by Anderson (1982).

The youngest woodland is dominated by white ash (Fraxinus americana) and American elm. Other species present, in order of decreasing frequency, are boxelder, wild black cherry (Prunus serotina), American sycamore (Platanus occidentalis), hackberry (Celtis occidentalis), sugar maple (Acer saccharum), red maple (Acer rubrum), and silver maple (Acer saccharinum) (Table 2-2). The understory is dominated by multiflora rose (Rosa multiflora), Japanese honeysuckle (Lonicera japonica), and blackberry (Rubus spp.) (Table 2-3).

A woodland area identified as intermediate in maturity is dominated by shellbark hickory (Carya lasciniosa), American elm, hackberry, and wild black cherry. Other species present, in order of decreasing frequency, are northern red oak (Quercus borealis), shingle oak (Quercus imbricaria), white ash, eastern red cedar (Juniperus virginiana), chestnut oak (Quercus prinus), eastern cottonwood, black walnut (Juglans nigra), slippery elm (Ulmus rubra), honey locust (Gleditsia triacanthos), black locust, silver maple, boxelder, and common persimmon (Diospyros virginiana) (Table 2-2). Dominant herbaceous species include meadow fescue and Kentucky bluegrass.

In both young and intermediate woodlands, American elm is a co-dominant, which is probably a consequence of continual disturbance by grazing and understory removal or alteration. The difference in composition between intermediate and young woodlands most likely reflects varying degrees of disturbance, allowing more opportunistic species to colonize these areas. These two wooded areas have six species in common, although the species vary in frequency.

A more mature woodland, also characteristic of a mixed floodplain community type, occurs on site. American elm is the dominant species, with slippery elm, sugar maple, Ohio buckeye (Aesculus glabra), boxelder, black walnut, mockernut hickory (Carya tomentosa), bitternut hickory (Carya cordiformis), chestnut oak, northern red oak, wild black cherry, and Kentucky coffee tree (Gymnocladus dioica) also present (Table 2-2). The subcanopy is dominated by sugar maple and Ohio buckeye (Table 2-3). Dominant herbaceous species include common chickweed and Kentucky bluegrass.

Species common to all three woodlands (American elm, hackberry, and wild black cherry) are those typical of disturbed areas where gaps occur in the canopy. Wild black cherry is a "release" species (colonizes areas rapidly after removal of the canopy), while American elm and hackberry are opportunistic species. Hackberry adapts and flourishes in a wide range of environmental conditions and may be found as a canopy or subcanopy species.

A riparian woodland borders Paddy's Run. Based on the dominant species present (eastern cottonwood, hackberry, American elm, and boxelder), the riparian woodland resembles a maple-cottonwood-sycamore floodplain forest (Anderson 1982). Due to streambed alteration made to reduce bank erosion, other species have colonized the floodplain area, resulting in a more diverse forest habitat.

The streambed alteration has yielded two distinct riparian woodland areas, R1 and R2 (Table 2-2). The dominant species in R1 (Figure 2-3) are the eastern cottonwood, hackberry, and boxelder. Co-dominants include black walnut, swamp white oak (Quercus bicolor), American elm, American sycamore, and honey locust. Additional species include (in order of decreasing frequency), bitternut hickory, osage orange (Maclura pomifera), hawthorn (Craetaegus sp.), black willow (Salix nigra), shagbark hickory, chinquapin oak, shingle oak, wild black cherry, sugar maple, and white ash. Trumpet creeper (Campsis radicans) and hackberry are co-dominants in the understory (Table 2-3). Garlic mustard (Alleria officinalis) is a common herbaceous species.

The dominant species in R2 are American elm and boxelder (Table 2-2). Other species present include black walnut, hackberry, slippery elm, American sycamore, Ohio buckeye, eastern cottonwood, swamp white oak, honey locust, silver maple, and white ash. Common herbaceous species include chickweed and brome grass. Boxelder and poison ivy occur frequently in both riparian forests.

2.2.2 Fauna

The wildlife species occupying the FMPC are discussed in this section. These species are indigenous to similar habitats occurring throughout southern Ohio and Indiana and northern Kentucky. The major categories are mammals, birds, amphibians and reptiles, and terrestrial arthropods.

2.2.2.1 Mammals

A variety of mammals, including big game, furbearers, small game, and small non-game mammals, uses the habitats on the FMPC. Mammals may represent a pathway for potential human exposure to contaminants in the FMPC environs. Potential pathways are via consumption of game, such as deer and rabbits, and via fur animals such as the fox, which may in turn be exposed to contaminants by eating contaminated prey. Indeed, the mammal group most at risk for contaminant release from the FMPC is the predators, including the short-tailed shrew, coyote, red fox, and feral (wild) cat. However, except for the short-tailed shrew, these predators have large ranges relative to the small mammals on site, and would therefore spend a smaller proportion of their lives in contaminated areas than would species with small home ranges. Mammal populations on the FMPC were described by Facemire et al. (1990) (Appendix C). Results of these studies and other less detailed studies are summarized below.

The short, dense pine forests introduced on the FMPC are a preferred habitat for white-tailed deer (Odocoileus virginianus), which are the only big game mammals observed on site. The combination of dense cover, mowed strips between tree rows, and a buffered thermal microenvironment is attractive to deer. A population of 15 to 18 deer was estimated on site by Facemire et al. (1990), who considered this estimate conservative.

Medium-sized mammals that may be considered furbearers and/or taken as food for human consumption are common on the FMPC. Species observed during field investigations include the coyote (Canis latrans), red fox (Vulpes vulpes), opossum (Diadelphis virginianus), raccoon (Procyon lotor), groundhog (Marmota monax), eastern cottontail (Sylvilagus floridanus), and fox squirrel (Sciurus niger).

Populations were estimated for the fox squirrel and eastern cottontail, the two species most likely to be consumed by humans (Facemire et al. 1990). The fox squirrel primarily uses deciduous forest and second growth vegetation, which occupies about 73 hectares on the FMPC. Fox squirrel density in prime habitat on site was estimated at 2.50/ha using a time-area count technique (Facemire et al. 1990). It was therefore estimated that about 183 fox squirrels were present within the FMPC boundaries.

The introduced pine woodlands on site are a preferred eastern cottontail habitat, where density estimates ranged from approximately 1.4 to 4 rabbits per hectare (61 percent of the FMPC population). Low to moderate numbers of cottontails occupied the deciduous woodland, riparian, and reclaimed fly ash pile habitats. Based on density estimates, approximately 140 eastern cottontails were estimated to be present within the FMPC boundaries. This estimate was considered lower than density estimates for comparable offsite habitats. The low density appears to be related to current FMPC land management practices (brush clearing, grazing, and mowing). However, cottontail populations can also vary dramatically from year to year.

An important non-native predator, the feral cat, was commonly observed within the FMPC boundaries, particularly in the introduced pine habitats. As evidenced by the number of feeding sites (collections of bird feathers), feral cats may have an adverse impact on FMPC small mammal and bird populations.

Five non-game small mammal species were captured during studies conducted in 1986 and 1987 (Facemire et al. 1990). The white-footed mouse (Peromyscus leucopus) was present in the highest numbers overall, while the short-tailed shrew (Blarina brevicauda) occurred in the largest number of habitats. The meadow vole (Microtus pennsylvanicus), meadow jumping mouse (Zapus hudsonius), and eastern chipmunk (Tamias striatus) are the other three species of small mammals known to be present on site.

2.2.2.2 Birds

Birds are a potential pathway for human exposure to contaminants in the FMPC environs. The mourning dove and bobwhite are the species most likely to be eaten by humans. These species tend to have relatively broad home ranges, and could transport radionuclides off site. However, the broad range would also result in a decreased period of time spent on site. The potential exists for contaminant uptake by raptors foraging over the FMPC. Raptors feed on small mammals, amphibians, reptiles, fish, other birds, and insects, and would tend to concentrate any contaminants in their own tissue.

Bird populations using FMPC habitats were censused as follows: breeding birds (June-July 1986); winter birds (February-March 1987); and spring migrant birds (April-May 1987). These census studies performed by Facemire et al. (1990) resulted in the identification and quantification of 98 species of birds (Appendix D).

The most common breeding species in all habitats were the mourning dove (Zenaida macroura), American robin (Turdus migratorius), blue jay (Cyanocitta cristata), American crow (Corvus brachyrhynchos), American goldfinch (Carduelis tristis), northern bobwhite (Colinus virginianus), and common grackle (Quiscalus quiscula). The species occurring in greatest abundance were the goldfinch, song sparrow (Melospiza melodia), and American robin. Overall, the avian diversity is considered high within FMPC habitats, because of the edge effect created by many small, discontinuous patches of available habitat (Facemire et al. 1990).

The most common wintering species were the song sparrow, Carolina chickadee (Parus carolinensis), and mourning dove. Several other species wintering throughout a large number of habitats included the downy woodpecker (Picoides pubescens), blue jay, northern cardinal (Cardinalis cardinalis), American robin, and American goldfinch. A total of 37 species of wintering birds were observed on the FMPC.

Twelve avian species considered spring migrants were observed on the FMPC. Lower than expected numbers of spring migrants were recorded on site and throughout the greater Cincinnati area, due largely to the unseasonably warm and dry spring weather of 1987.

Raptor species observed on site included the northern harrier (Circus cyaneus), red-shouldered hawk (Buteo lineatus), Cooper's hawk (Accipiter cooperii), red-tailed hawk (Buteo jamaicensis), and American kestrel (Falco sparverius). In addition, two owl species, the eastern screech owl (Otus asio) and great horned owl (Bubo virginianus), were commonly observed. Census studies for owls resulted in the identification of 15 screech owl territories, 29 territorial pairs of screech owls, and two pairs of great horned owls.

Call-count stations (Brown et al. 1978) were used to estimate populations of the bobwhite. A minimum of 18 males was estimated to be using FMPC habitats for breeding purposes. Using various life history parameters (sex ratio, nesting success, renesting attempts, clutch size, and juvenile survival), 142 bobwhite were estimated for the available habitat. Researchers conducting this survey considered this estimate somewhat conservative because the census was made during the final weeks of the breeding season (Facemire et al. 1990).

The highest quality breeding habitat for bobwhite on site was determined to be in the waste storage area and the far northwestern corner of the site. Other important breeding habitat occurred west of Paddy's Run along the western FMPC boundary, the far north-central site boundary, and the south-central site boundary.

2.2.2.3 Amphibians and Reptiles

Amphibians and reptiles are not widely used as a food source for humans in the FMPC vicinity. Limited use may be made of species such as the snapping turtle or frogs. Therefore, any contaminant uptake by amphibians and reptiles in and around the FMPC would tend to have a greater effect on predaceous birds, mammals, and fish than on humans.

Amphibians and reptiles occupying habitats within the FMPC were expected to be similar in species composition to similar habitats in the region. Documentation of amphibians and reptiles was limited to incidental sightings, and a list is presented here as Appendix E (Facemire et al. 1990).

Ponds on site supported the American toad (Bufo americanus) and the spring peeper (Hyla crucifer). Paddy's Run and adjacent woodlands supported a number of eastern box turtles (Terrapene carolina), and the snapping turtle (Chelydra serpentina) was observed in a pool in Paddy's Run.

Snakes were the most commonly observed reptiles, with the eastern garter snake (Thamnophis sirtalis), Butler's garter snake (T.

butleri), and black rat snake (Elaphe obsoleta) occurring in upland habitats. Paddy's Run supported the northern water snake (Nerodia sipedon) and the queen snake (Regina septemvittata).

2.2.2.4 Terrestrial Arthropods

Terrestrial arthropods are not generally consumed by humans and therefore do not represent a contaminant source directly through ingestion. However, arthropods are eaten by a number of wildlife species, including fish, amphibians and reptiles, birds, and mammals, which in turn may be consumed by humans.

Collections of terrestrial arthropods were made from the FMPC during July 1986 (Facemire et al. 1990). Organisms collected included insects, insect larvae, spiders, mites, ticks, and a few gastropods. Approximately 130 insect families from 15 orders were represented in the collections (Appendix F). Leaf hoppers were consistently abundant across all the habitats sampled, while less abundant groups found on the FMPC included short-horned grasshoppers, leaf beetles, springtails, fruit flies, dark-winged fungus gnats, ants, bees, and wasps.

Ungrazed pastures supported the greatest number of insects (Facemire et al. 1990). The riparian woodland supported the fewest insects, primarily because of the lack of understory vegetation. It is expected that butterflies, moths, skippers, and ground dwelling beetles were underestimated because of the sample methodology (netting) used.

Orbweaving spiders were abundant in riparian areas and within the reclaimed fly ash pile habitat. Other spiders, particularly ground dwellers, were not fully sampled using the netting methodology, but are quite common within FMPC habitats. Mites and ticks also were not fully sampled, but were common sitewide. Woodlot and riparian habitats contained a number of snails.

2.3 AQUATIC ORGANISMS

Aquatic organisms include fish, benthic macroinvertebrates, and wetland plant species present within the FMPC and the site vicinity. This section summarizes the studies to date which characterize the aquatic environment of the FMPC and vicinity. Generally, these studies describe habitats, species composition, and relative species abundances, and summarize water quality of particular habitats. The habitats which have been studied are Paddy's Run and the Great Miami River.

2.3.1 Fish

Fish are a relatively sensitive indicator of environmental quality, as well as a potential pathway for contaminant intake by humans through ingestion (Figure 2-4). Fish are important in studies of water quality because they complete their entire life cycle in the water, are the end receptor of most aquatic food webs, and their biomass is dependent on primary and secondary productivity. The distribution and relative abundances of fish are important variables used to assess the health of fish populations and aquatic habitat quality. Changes in total numbers of fish and numbers of individuals per species can be related to major pollution sources and to the presence of tributary confluences.

It has been suggested that fish may be too mobile or difficult to catch to be a practical environmental monitoring group (OEPA 1985). However, many stream and river fishes are sedentary, particularly in the summer months. Additionally, fish found in Paddy's Run normally live in isolated pools for several months of the year, because of the intermittent nature of this stream.

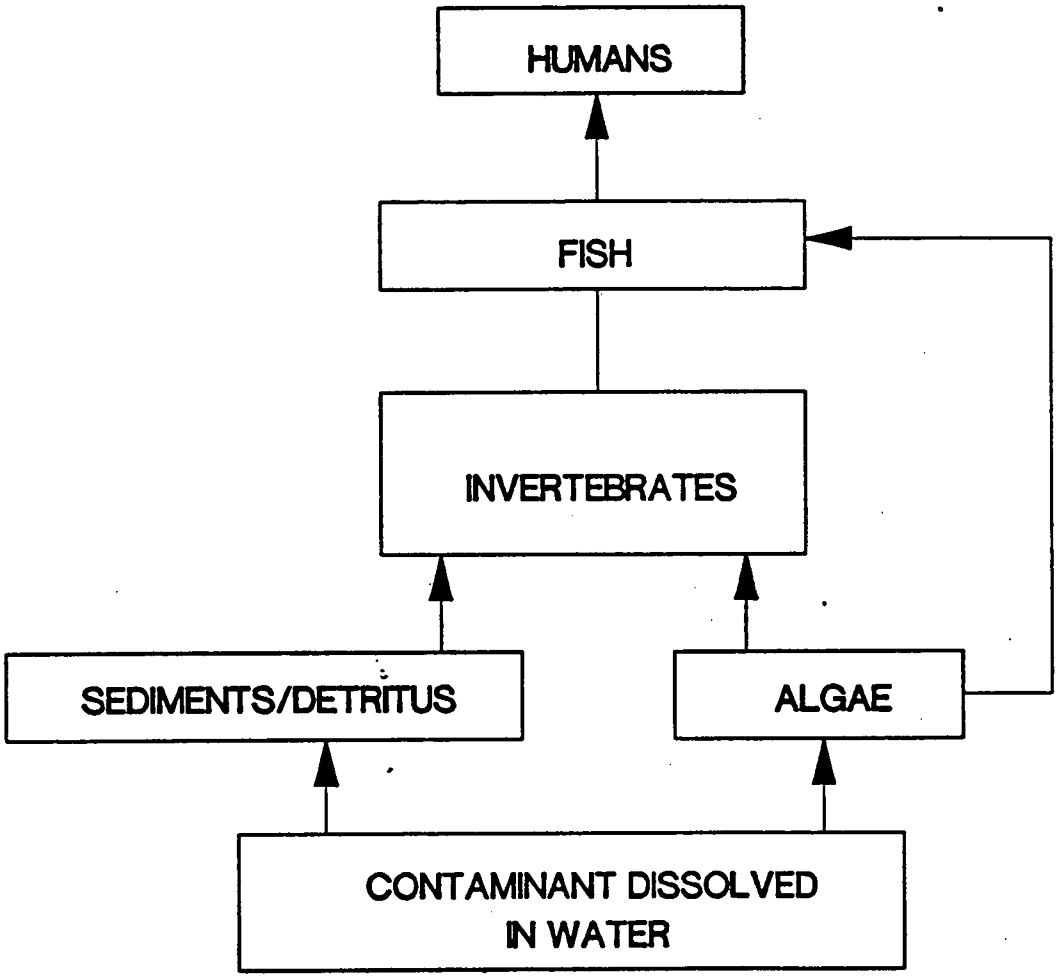


FIGURE 2-4. GENERALIZED AQUATIC FOOD WEB AND FLOW DIAGRAM OF POTENTIAL CONTAMINANT UPTAKE BY HUMANS

HEB'22

2.3.1.1 Paddy's Run

Studies of the fishes of Paddy's Run have recorded species composition (Tarzwell 1952, Bauer et al. 1978) and species composition, abundance, and diversity (an index of total numbers of organisms and relative species abundances) (Facemire et al. 1990). The more recent studies identified 22 fish species (Appendix G).

During the June 1986 sampling by Facemire et al. (1990), Paddy's Run was dry from the vicinity of the K-65 silos to just south of the FMPC boundary. Pool substrate consisted of rocks, gravel, sand, and large deposits of silt, while riffle substrates were primarily large rocks and gravel. The deepest water encountered was approximately one meter. The bluntnose minnow (Pimephales notatus), creek chub (Semotilus atromaculatus), and stoneroller minnow (Campostoma anomalum) were the most abundant fish species.

Other common fishes that occurred in smaller numbers included the rosefin shiner (Notropis ardens), Johnny darter (Etheostoma nigrum), orangethroat darter (Etheostoma spectabile), and fantail darter (Etheostoma flabellare). A large number of specimens collected during this study were under 20 mm, representing young of the year.

March 1987 samples were taken from the same and similar pool and riffle habitats sampled in June 1986. The bluntnose minnow, stoneroller minnow, and spotfin shiner (Notropis spilopterus) were the most abundant fish species. Other common fishes that occurred in smaller numbers included the rosefin shiner, orangethroat darter, and fantail darter.

June 1987 samples were taken from the same pool and riffle habitats sampled in March 1987. The stoneroller minnow, orangethroat darter, and Johnny darter were the most abundant fish species.

Other common fishes that occurred in smaller numbers included the bluntnose minnow, rosefin shiner, silverjaw minnow (Ericyma buccata), and creek chub. Generally, fish diversity for the combined Paddy's Run sites increased from June 1986 to June 1987 (Facemire et al. 1990).

2.3.1.2 Great Miami River

The Ohio Environmental Protection Agency (OEPA 1985) conducted intensive fishery surveys along 91 miles of the Great Miami River and the lower reaches of five tributary streams during 1980. The reach of the river receiving effluent from the FMPC outfall and runoff via Paddy's Run was included in the OEPA study. Sixty-four fish species and six hybrids were collected during these studies (Appendix H). Since 1900, 106 species and six hybrids have been recorded from this river reach (Trautman 1957, 1981). The 42 fish species previously observed but not collected during the OEPA study are listed in Appendix I. While the apparent drop in the number of species could be indicative of changing conditions, a direct comparison of the data sets introduces significant uncertainty due to differences in the length of time over which the data were collected, the number of collections made, and the sampling methods used. In addition, the OEPA study selectively sampled from near-shore habitat (OEPA 1985).

WMCO has sampled three stations on the Great Miami River on an annual basis since 1984 (WMCO 1987a). The stations are located near the Bolton Water Works, below the FMPC outfall, and at the confluence with Paddy's Run. Twenty fish species were captured or observed during the WMCO 1987 sampling (WMCO 1987a). Of these species, the gizzard shad (Dorosoma cepedianum), freshwater drum (Aplodinatus grunniens), carp (Cyprinus carpio), and striped bass (Morone saxatilis) were the most commonly captured.

The biological assessment of the Great Miami River conducted by OEPA (1985) examined percent similarity, which reveals areas of similar and dissimilar community composition, and relative composition based on numbers and weight. These analyses were applied to all reaches along the river, including the segment (10) that could potentially be affected by FMPC effluents and runoff. Segment 10 encompasses River Mile 24.7 to River Mile 9.2. The FMPC effluent line lies at River Mile 24.7. Fish community numerical dominants in Segment 10 included shiners, sunfish, catfish, drum, gizzard shad, carp, and goldfish. Dominants of the fish community for Segment 10 in terms of biomass (48.8 kilograms/kilometer) included carp, goldfish, catfish, drum, gizzard shad, and suckers. Approximately 185 fish/kilometer were captured within Segment 10 waters.

Composite diversity indices (which include both relative species numbers and relative weights of species) for Segment 10 show that this segment of the Great Miami River is capable of supporting a well-balanced, healthy fish community (OEPA 1985). Segment 10 had a composite index (7.9) considered "Good," indicating attainment of Clean Water Act goals. The conditions met by Segment 10 included: 1) usual association of expected species, 2) presence of sensitive species, 3) high species diversity (many individuals of many species), and 4) a composite index between 7.0 and 9.5. In addition, WMCO (1987a) found no indication of aberrant sex ratios in fish species occurring at the three stations sampled. None of the sex ratios determined were significantly different from a 1:1 (male:female) ratio for gizzard shad, carp, suckers, and striped bass. Sex ratios deviating from 1:1 can be an indication of stress.

External anomalies (sublethal stress indicators) including tumors, lesions, eroded fins, and parasites were assessed during the OEPA (1985) study. Background rates were between one and three percent for the various anomalies considered. Segment 10 averaged 2.8 percent anomalies, within the background range. However, this average is based upon a range of readings from 0.5 percent at River Mile 17.1 to 6.0 percent at River Mile 23.6, which lies 1.1 miles below the FMPC outfall. The highest percentage of anomalies observed occurred below Dayton at River Mile 65.9, where 24.8 percent of the fish sampled were affected.

2.3.2 Benthic Macroinvertebrates

Benthic macroinvertebrates (benthos) are aquatic organisms, including insects, insect larvae, annelid worms, snails, etc., that are generally found in the bottom substrates such as sediments, muck, and cobble. Gamefish, waterfowl, crayfish, and other organisms which feed on benthos are often eaten by humans. Therefore, the benthos community represents a potential indirect source of contaminant transmission to humans (Figure 2-4). Aquatic habitat supporting benthos occurs in Paddy's Run, ponds and depressions on the FMPC, and in the Great Miami River.

Benthos organisms have a number of characteristics useful as indicators of water quality (OEPA 1985) that include:

- Forming permanent or semipermanent stream communities;
- Being less transient than fish;
- Being less sporadic in occurrence than microorganisms (algae, bacteria, etc.); and
- Occurring in statistically significant numbers, even in small streams.

Environmental factors, both adverse and favorable, affect community structure and species composition of benthos. Since benthos are relatively short-lived, the environmental factors under consideration have probably existed throughout the life of the organisms present. For this reason, both short term and long term exposure to contaminants may alter the structure of the benthic community (OEPA 1985). Both the type of contaminants and the concentrations in which they are found affect the degree of change within the benthic community.

Aquatic habitats contain stable, well-balanced benthic communities when water quality is high (OEPA 1985). In this situation, pollution sensitive organisms are found, including stoneflies, mayflies, and caddisflies. Where water quality is degraded, only more tolerant organisms, such as oligochaetes, dipterans, and pulmonate snails, are found (OEPA 1985). Extremely toxic conditions generally preclude the development of any benthic community.

The species composition and number of organisms are equally important when considering the benthic community as an indicator of water quality. Usually the number of taxa is greater than 30 in high quality waters and less than 20 in areas with degraded or lower quality waters (OEPA 1985).

2.3.2.1 Paddy's Run

Facemire et al. (1990) collected benthic macroinvertebrate samples from 11 pool and riffle sites in Paddy's Run. Riffles sampled flowed over cobble, pebbles, and gravel; were rapid to slow in movement; and had a mean depth of approximately 16 cm. Pools were characterized by fine gravel, sand, and silt bottom substrate; very slow water movement; and averaged approximately 37 cm deep (Facemire et al. 1990). Eight sites were sampled within the FMPC boundaries during the winter of 1986 (Facemire et al. 1990). Two sites, one north of the FMPC boundary and one south of the FMPC boundary, were resampled during the winter of 1987 (Facemire et al. 1990). Paddy's Run is an intermittently flowing stream and much of the available streambed habitat was dry during this sampling period.

The type and number of benthos collected from Paddy's Run were typical of streams throughout southwestern Ohio (Facemire et al. 1990). Fifty-six taxa (counted as the lowest taxa to which organisms were identified) of benthos were collected from Paddy's Run (Appendix J). Four taxa, the non-biting midges (chironomidae) riffle beetle (Stenelmis sp.), mayfly (Caenis sp.), and stonefly (Allocapnia sp.), were present at each of the ten riffles sampled. Also common throughout the length of Paddy's Run were the mayfly (Stenonema bipunctatum), isopod (Lirceus fontinalis), caddisfly (Cheumatopsyche sp. and Hydropsyche sp.), segmented worms (Oligochaeta), blackfly (Simulium sp.), and stonefly (Nemouridae). Chironomids were present at all pool sites sampled, with the largest numbers of individuals belonging to the genus Chironomus. Two other taxa, the mayfly and stonefly, were identified from four or more of the pools sampled.

Facemire et al. (1990) reported diversity values (Shannon and Weaver 1949) from 0.79 to 3.03 for ten sites on Paddy's Run, considering this typical of benthos community values for area streams. Diversity values reported by Pomeroy et al. (1977) for sites on Paddy's Run ranged from 1.80 to 2.21. These diversity values are similar to those reported for streams receiving moderate amounts of pollution (Wilhm 1967, Wilhm and Dorris 1968, Sheehan and Winner 1984).

2.3.2.2 Great Miami River

The OEPA water quality study (OEPA 1985) included an analysis of benthos from the Great Miami River. Segments 10 and 11 from this study comprise the Great Miami River mainstem from the FMPC to the confluence with the Ohio River (River Mile 24.7 to 0.0). Qualitative benthos data were collected at River Mile 22.5, which lies 2.2 miles downstream from the FMPC discharge point (River Mile 24.7). Quantitative data were collected at River Mile 15.1, 9.6 miles below the FMPC discharge point.

Diverse benthic communities were observed throughout Segments 10 and 11, resulting in a good water quality rating for this river reach. The benthic community "exhibited patterns of diversity and abundance generally consistent with large, organically enriched warmwater rivers," with only minor stresses noted (OEPA 1985). Segments 10 and 11 have exhibited an increasing trend in benthic diversity since the 1960's. In 1976, 15 taxa with a diversity index of 2.51 were collected at River Mile 22.1 (2.6 miles downstream of the FMPC discharge point). Twenty taxa with a diversity index of 2.47 were collected from the same site in 1977. In 1980, 26 taxa were collected on artificial substrate samplers at River Mile 22.5 (Appendix K). This collection was a qualitative sample. However, at River Mile 15.1, 27 taxa with a diversity index of 3.10 were collected using the same method during the same sampling period. Pomeroy et al. (1977) reported 13-18 taxa per site at three sites on the Great Miami River upstream from the confluence with Paddy's Run. Diversity values at these sites ranged from 2.23-3.06 for the samples collected. Streams that are considered "clean" usually have diversity index values between 3.0 and 4.0 (Wilhm 1970). The range of index values currently known for Ohio streams is 0.01 (grossly polluted) to 4.12 (very good water quality).

Sample sites below the FMPC outfall supported a total of 28 taxa, 26 of which were observed 2.2 miles downstream. At River Mile 15.1, the dominant species included caddisflies (60 percent), while mayflies and chironomids were also abundant (OEPA 1985). Very few oligochaetes, which tend to tolerate low water quality habitats, were observed. Overall, the quantitative and qualitative data collected from Segments 10 and 11 indicated little change in benthic composition throughout the segments and no apparent adverse effects on water quality related to the various discharges within the segments (OEPA 1985).

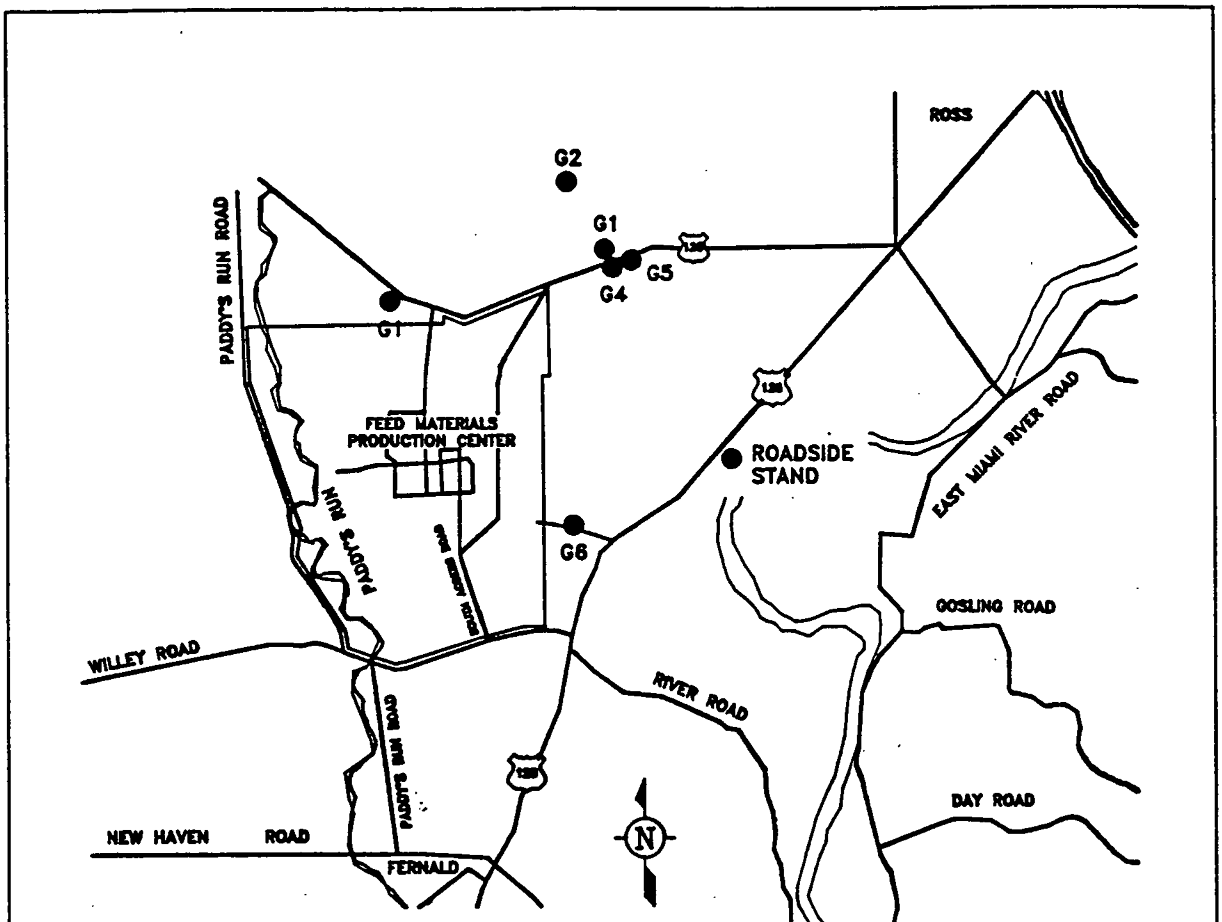
One species of amphibian, the cave salamander (Eurycea lucifuga), is recognized as state endangered (ODNR 1974) and is known to occur in the FMPC vicinity. Reported locations include the Mount Airy Forest, Groesbeck, one mile northeast of New Baltimore, and Sheits Road near Blue Rock Road (ODNR 1986). Surveys conducted to determine the distribution of the cave salamander and to identify potential habitat on the FMPC and in the immediate vicinity are described in Chapters 3 and 4 below.

Three raptors, the red-shouldered hawk (Buteo lineatus), Cooper's hawk (Accipiter cooperii), and northern harrier (Circus cyaneus) are listed as "Rare Species of Native Ohio Wild Animals" (ODNR, 1982), and have been observed on the FMPC (Facemire et al. 1990). One red-shouldered hawk was observed over the northernmost deciduous forest habitat of the FMPC. A northern harrier was sighted on one occasion northeast of the production facility.

The Cooper's hawk is considered an uncommon but regular breeding species in the Cincinnati vicinity (CNC 1978) and a threatened breeding species in Ohio (ODNR 1982). This species was frequently observed during the summer over the introduced pine woodlands and pasture habitat throughout the FMPC (Facemire et al. 1990), and is considered an uncommon to common fall migrant and winter resident in Ohio (Trautman and Trautman 1968).

The Cincinnati crayfish (Orconectes sloanii) has been considered threatened, following field studies to determine the species distribution (Jezerinac 1986). Cincinnati crayfish were collected in Paddy's Run during FMPC characterization studies (Facemire et al. 1990). Historically, this crayfish has been collected primarily in tributaries of the Great Miami River system south of the confluence of Greenville Creek. Factors currently affecting the Cincinnati crayfish include urban development, stream impoundment, siltation, pollution, and competition with other crayfish species, particularly O. rusticus, which was also found in Paddy's Run.

Specimens of the cobblestone tiger beetle (Cicendela margipennis), which is under review by the U.S. Fish and Wildlife Service for possible inclusion in threatened or endangered species lists, were found during the Indiana bat survey. This discovery is described in Chapter 4 below.



LEGEND:

Collection Site	Location and Coordinates
G1	3881 Cincinnati-Brookville Road
G2	4033 Christian Road
G3	3418 Cincinnati-Brookville Road
G4	Cincinnati-Brookville Road
G5	3133 Cincinnati-Brookville Road
G6	N 480,250 E 1,383,200
Roadside Stand	0.8 Miles North of Willey Road on State Highway 128, East Side

Indiana Control Areas
(Not Shown on Map)

Vegetation Sampling Sites

I1 5041 Highland Court Rd. Brookville, In.
N680,923 E687,671

I2 Same as I1

I3 N672,048 E687,671

I4 N664,098 E689,594

0 1000 2000
SCALE IN FEET

FIGURE 3-1. LOCATION OF SAMPLING SITES FOR GARDEN PRODUCE AND AGRICULTURAL CROPS IN THE FMPC VICINITY

58

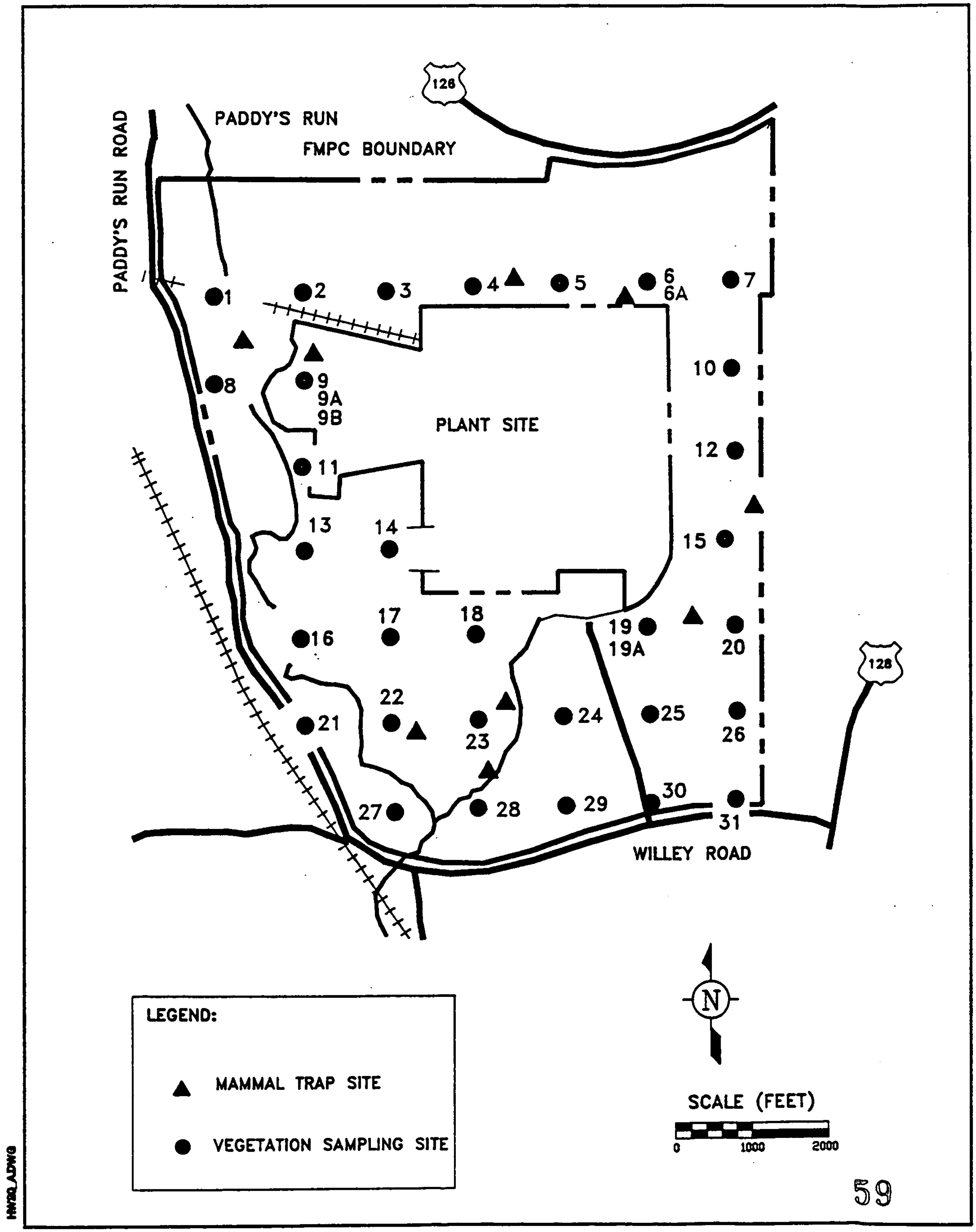


FIGURE 3-2. LOCATION OF VEGETATION/SOILS AND MAMMAL SAMPLING SITES ON THE FMPC

was collected from a point diagonally opposite the vegetation sampling point, always within 0.5 m of the vegetation sample. Collection procedures were as follows:

- Shears, trowels, and shovels were pre-washed at the decontamination facility using biodegradable soap, rinsed thoroughly with deionized water, and dried using alcohol wipes and paper towels.

- Following placement of the 0.5 m X 0.5 m quadrat, a staging area (polyethylene sheet) was placed on the ground and sample utensils were laid out, including:

  - Shears
  - Trowel
  - Aluminum foil
  - Zip-loc bags
  - Site map
  - Polyethylene wash bottles
  - Biodegradable soap
  - Paper towels
  - Wash receptacle
  - Sample labels
  - Cooler with blue ice
  - Marking pen
  - Field notebook
  - Deionized water
  - Methyl alcohol
  - Alcohol wipes

- Vegetation samples were collected by cutting shoots at ground level with the shears, dividing the material into major groups (e.g., grass, forb, shrub, moss, pine needle), and placing the material on a sheet of aluminum foil. Samplers wore disposable latex gloves, which were changed after use at each site to prevent sample cross-contamination while clipping vegetative shoots and digging root samples.

- The plant material was wrapped in the aluminum foil sheet and placed in a zip-loc bag.

- Sample labels were put on each zip-loc bag indicating the sample location, date, time, sample type, sample collectors, analytical parameters, and a dedicated sample number. This information was also recorded on a sample collection log sheet and in the field notebook.

- This procedure was repeated for root samples to a depth of approximately 15 cm at each sample site. To the extent possible, earth was removed from root samples prior to packaging.

- The samples were stored in a cooler with blue ice while other sites were being sampled.
- Shears, trowels, and shovels were decontaminated by washing with biodegradable soap and deionized water, drying with methyl alcohol, alcohol wipes, and paper towels, and were then placed in a clean polyethylene bag.
- Used latex gloves, wipes, paper towels, and label backing were placed in a polyethylene trash bag for appropriate disposal by WMCO.
- Sample bags were sealed with chain-of-custody tape and placed in a locked, dedicated freezer to await shipment to the analytical laboratory.
- Chain-of-custody forms and request-for-analysis forms were prepared to accompany samples to the analytical laboratory. Samples were shipped by the sample coordinator to the analytical laboratory in sealed coolers packed with blue ice.

Analytical parameters are presented in Section 3.1.3.

Sampling of farm and garden produce was coordinated with sampling conducted by WMCO Environmental Compliance personnel, with assistance from the Public Affairs Department. Under the grower's supervision, RI team representatives collected samples of the produce available, e.g., fruits, leafy vegetables, grains, and root crops, and a representative soil sample. Sample collection and handling followed the procedures listed previously, except that a quadrat-bounded sample area was not used.

Four wetland sites were sampled (Figure 3-2). Site 6A is a drainage ditch on the county line at the southeast corner of the northern pine plantation. Both cattail and sedge samples were collected from this site. Site 9A, a seep below the Waste Storage Area on the eastern bank of Paddy's Run, was sampled for vegetation and soil. Site 9B, a pond and wetland system occupying the drainage ditch below the sanitary landfill and collecting drainage water from the north and northwest of the FMPC, provided samples of cattail. Site 19A, the drainage ditch near the main parking lot, was also sampled for cattails. Two algae samples were collected from Paddy's Run in 1988 at sites PR-1 and PR-2A (Figures 3-2 and 3-3). PR-1 was located at the northern property line of the FMPC, above the zone of potential FMPC influence, and PR-2A was located just downstream from the C & O Railroad bridge.

Uptake of radionuclides by plants relative to the concentration of radionuclides in the soil can be represented by a concentration ratio (CR), calculated as

$$CR = \frac{\text{radionuclide activity per weight of plant}}{\text{radionuclide activity per weight of soil}}$$

A CR greater than one can indicate potential biomagnification of radionuclides, that is, concentration of them by plants, although a number of factors can affect CRs, as discussed in Chapter 4.0. CRs were calculated where possible, that is, where radionuclide concentrations were above detection limits for both soil and vegetation samples at a given site. Means, standard deviations, confidence intervals, and coefficients of correlation (r) among the variables measured were calculated according to Sokal and Rohlf (1981).

3.1.2 Fauna Sampling

Site-wide and offsite faunal samples included mammals and fish. Sample locations were selected (1) in areas where the potential for contamination was high (i.e. near the fly ash pile, incinerator, and waste pits), (2) in a drainage pond below the sanitary landfill, (3) in Paddy's Run (on and off site), and (4) in the

Great Miami River (up- and downstream from the FMPC outfall). When available, samples were also taken from road-killed mammals. All faunal samples were collected under Scientific Collecting Permit No. 228 from the Ohio Department of Natural Resources, Division of Wildlife.

3.1.2.1 Mammals

Tissue from small mammals was collected from below the fly ash pile and near Waste Pit 5, as well as from the pine plantation just north and northeast of the Production Area (Figure 3-2). Small mammal samples included deer mouse, shrew, and cottontail rabbit. Tissue from two opossum was also analyzed as well as the kidney and liver of a road-killed white-tailed deer, southwest of the Production Area near the pine plantation.

Mammals were captured using a combination of live and snap traps. Traps were baited with rolled oats, apple, carrot, or peanut butter, as appropriate, and set in likely habitat. Larger mammals constituted individual samples, while small mammals were composited for each trap site. Samples were prepared as follows:

- Animals were placed in appropriately labeled zip-loc bags and stored in a locked, dedicated freezer until shipment to the analytical laboratory. Frozen samples were shipped via overnight courier in a cooler packed with blue ice to maintain sample integrity.
- All dissection of mammal tissue was performed in the laboratory to minimize the potential for cross-contamination.
- Decontaminated scalpel, forceps, and shears (decontaminated by washing in biodegradable soap, rinsing with deionized water, and wiping with an alcohol wipe) were used to excise tissues.
- Disposable latex gloves were worn to prevent contamination to workers and cross-contamination of samples. Gloves were disposed of after each use.

- Samples of muscle, internal organs (liver, kidney, and gonads), and/or bone were excised and placed on aluminum foil.
- Individual samples were wrapped in foil and placed in a zip-loc bag with the appropriate sample label.
- Each sample was recorded on chain-of-custody and request-for-analysis forms.

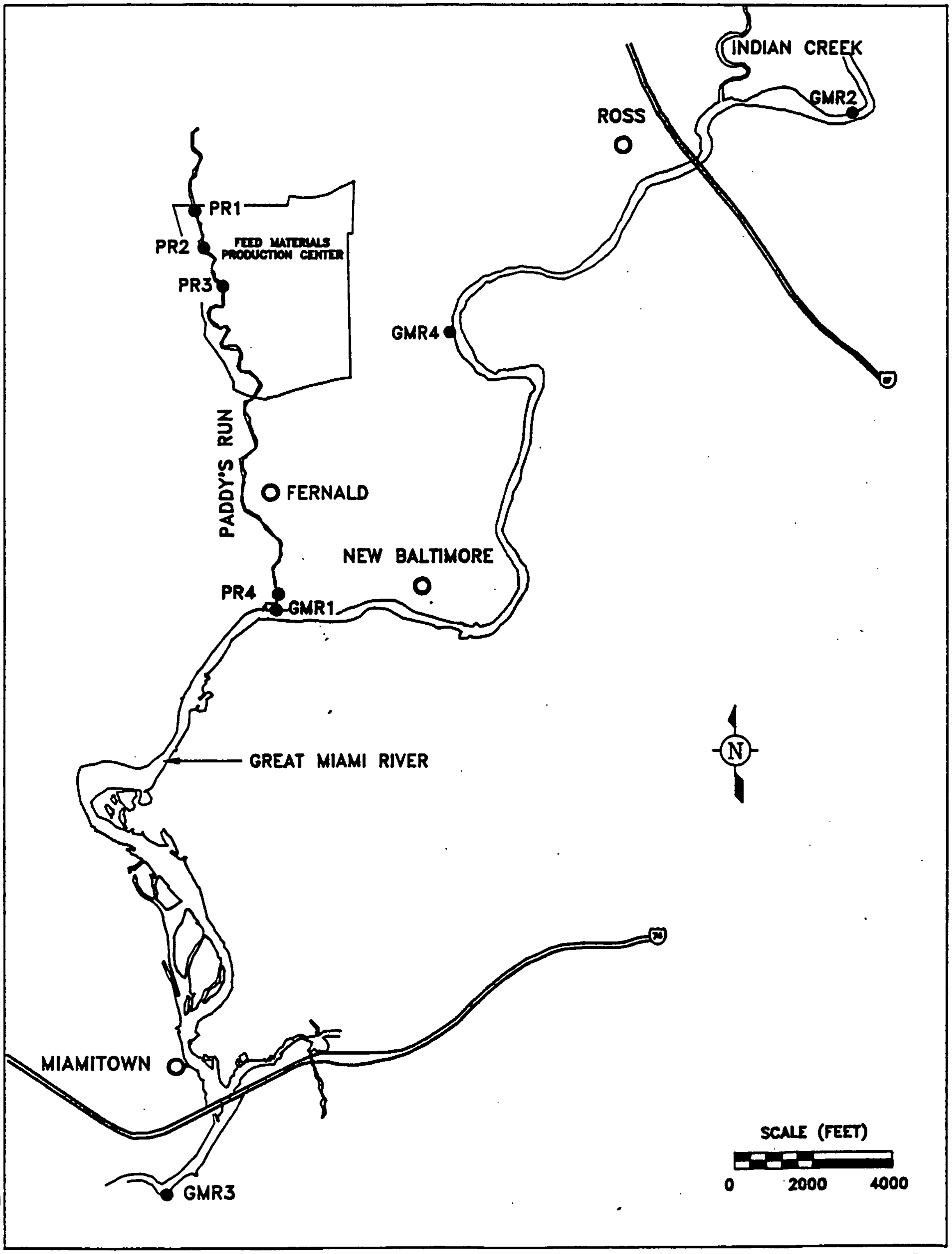
3.1.2.2 Fish

Fish were collected from four sites each on Paddy's Run and the Great Miami River, and from a small drainage pond north of the Production Area in 1987 (Figure 3-3). PR-1 was located at the northern property line of the FMPC. PR-2 was located where the C & O Railroad crosses Paddy's Run. PR-3 was located downstream of PR-2, and PR-4 was just above the confluence of Paddy's Run and the Great Miami River (Figure 3-3).

The sites on the Great Miami River were located near the Bolton water treatment plant upstream from the FMPC effluent line (GMR-2); just below the discharge point of the FMPC effluent line (GMR-4); at the confluence with Paddy's Run (GMR-1); and approximately 1 mile south of I-75 (GMR-3) (Figure 3-3).

Three samples of fish were collected and analyzed for radionuclides from a small pond at site 9B (Figure 3-2) just north of the C & O railroad spur near the outer fence on the northwest corner of the FMPC.

A combination of techniques, e.g., backpack shocker, seining, and dip netting was used to capture fish species for laboratory analyses. The small pond was sampled using a hand-held seine (1 m x 3 m). Two sweeps of the pond were sufficient to obtain specimens necessary for radionuclide analyses.



65

FIGURE 3-3. AQUATIC SAMPLING LOCATIONS ON AND NEAR THE FMPC

Paddy's Run consisted of only a few small pools with short riffle areas at the time of sampling. A combination of electrofishing and seining was used to collect representative fish samples from each aquatic habitat. Each pool was sampled using a Coffelt Model BP-4 backpack shocking unit equipped with two 5-foot electrode handles. Fish shocked to the surface were captured in a hand-held dip net and transferred to a collecting pail. After approximately 1/2 hour of use at each collection site, the backpack shocking technique was replaced by seining to adequately sample smaller fish species in the shallower waters. Fish captured were identified, a sufficient number or mass retained for analyses, and the remainder returned to the water.

The Great Miami River was relatively low at the time of sampling. Therefore, fish collection was possible by wading and using both the Coffelt Model BP-4 backpack shocker and seines. Deeper pools were sampled from the shore using a baited hook and line. Sample stations along the Great Miami River were approximately 100-150 meters long. Electrofishing was used along the length of the sample station, followed by seining. Fish captured were identified, a sufficient number or mass retained for analyses, and the remainder returned to the water.

Following collection, fish samples were prepared as follows:

- Holding pails and pans, rubber gloves, and fillet knives were pre-washed at the decontamination facility, using biodegradable soap, rinsed thoroughly with deionized water, and dried using alcohol wipes and paper towels.
- Samplers wore textured rubber gloves to prevent sample cross-contamination and aid in handling fish specimens while sorting, measuring, and weighing the specimens.

- A staging area (polyethylene sheet) was prepared with the following sample utensils:

  - Field notebook
  - Site maps
  - Sample labels
  - Marking pen
  - Measuring board
  - Scales
  - Fillet knife
  - Aluminum foil
  - Zip-loc bags
  - Paper towels
  - Deionized water
  - Alcohol wipes
  - Cooler with blue ice

- Fish to be used for analysis were identified, measured, and weighed.

- Smaller fish were composited, larger fish were filleted, and sample tissue was placed on a dedicated sheet of aluminum foil.

- Fish tissue was wrapped in aluminum foil and placed in a zip-loc bag.

- Sample labels were put on each zip-loc bag indicating the sample location, date, time, sample type, sample collectors, and a dedicated sample number.

- The above information was recorded on a sample collection log sheet and in the field notebook.

- Samples were stored in a cooler packed with blue ice while other sites were being sampled.

- Equipment was decontaminated at the decontamination station by washing with biodegradable soap and deionized water, and drying with alcohol wipes and paper towels. All equipment was stored in plastic bags for transport to the next sampling location.

- Used wipes, paper towels, label backing and other refuse were placed in polyethylene trash bags for appropriate disposal by WMCO.

- Following collection of fish samples, the sample bags were sealed with chain-of-custody tape and placed in a locked, dedicated freezer to await shipment to the analytical laboratory. At this time both chain-of-custody forms and request for analysis forms were prepared to accompany samples to the analytical laboratory.

3.1.2.3 Benthic Macroinvertebrates

Benthic macroinvertebrate (benthos) samples were collected from Paddy's Run and the Great Miami River at the same time and locations that fish samples were collected (Figure 3-3). A Surber sampler (0.09 m^2 area) was used to collect benthos samples, with organisms from three collections composited to produce the final sample for laboratory analysis. Crayfish caught while seining for smaller fish were also sent to the analytical laboratory as benthos samples, although analytical results were derived separately for crayfish and composite samples of other macroinvertebrates.

3.2 CONTAMINANT ANALYSES

Biological resource samples were analyzed for the uptake of various contaminants from the FMPC process materials and stored wastes. Analyses were conducted for three basic types of contaminants: radiological, organic, and HSL inorganics.

Radiological analyses in 1987 included the isotopes of uranium (U-234, U-235, U-236, U-238), strontium (Sr-90), and cesium (Cs-137). Samples collected from some of the sites used for collection of radiological samples were analyzed for organic and HSL inorganic constituents as well. These analyses were conducted in 1988 on samples from approximately 8 percent of the initial sampling locations. Results are reported for 15 biological samples including five grass leaves, five grass roots, one composite minnow sample, two small mammal samples and two deer organ samples. Analytical parameters were as follows:

- Organic:
  - Anthracene
  - Butyl benzyl phthalate
  - Chlordane
  - Chrysene
  - DDT
  - Fluoranthene

- Nitrophenol
- PCBs
- Phenanthrene
- Pyrene

• Inorganics:
  - Fluoride
  - Sulfate

• Metals:
  - Aluminum
  - Arsenic
  - Barium
  - Cadmium
  - Lead
  - Mercury
  - Silver
  - Vanadium
  - Zinc

These samples were also analyzed for isotopic uranium, strontium-90, cesium-137, and technetium-99. Technetium-99 was added due to its presence in FMPC waste streams and to its solubility.

3.3 ACUTE AND CHRONIC TOXICITY

Acute and chronic toxicity measurements were made on wastewater discharged from the FMPC effluent line to the Great Miami River. This two-tiered approach is designed to determine both mortality (acute) and sublethal impairment (chronic). Specifically, acute toxicity tests show gross life-threatening impairment and sensitivity of organisms to relatively high levels of contaminants. Chronic tests are more sensitive to lower toxicant levels and can therefore be used to monitor for subtle responses to contaminants. Although not acutely life-threatening, impairments in variables such as fecundity, offspring survival, or growth rate can have long term effects on the survival of organisms in the natural environment.

Acute toxicity testing was performed on the cladoceran Daphnia pulex and the fathead minnow Pimephales promelas, following standard EPA protocols (Peltier and Weber 1985). Chronic toxicity testing was performed on the green unicellular alga Selanastrum capricornutum, the cladoceran Ceriodaphnia dubia, and the fathead minnow Pimephales promelas, again following standard EPA protocols (Horning and Weber 1985). The chronic tests thus examined the effects of FMPC effluent on the elements of a simple aquatic food chain, alga to invertebrate to fish.

Water for acclimating test organisms to the receiving water was collected August 18 and September 22, 1988 from the Great Miami River at the Ross Bridge, upstream from the FMPC effluent line. Grab samples of FMPC effluent were collected from Manhole 175 on September 24, 25, and 27, 1988. Water for controls and for making effluent dilutions was collected September 24 and 27, 1988 from the Great Miami River at the Ross Bridge site. All the tests described below were performed on five concentrations of FMPC effluent (100, 50, 25, 12.5, and 6.25 percent) diluted with Great Miami River water, and on a control of Great Miami River water.

3.3.1 Acute Toxicity Tests

Daphnia pulex neonates (newly hatched organisms less than 24 hours old) were tested at 20°C. Each effluent concentration and control was run in duplicate with ten organisms per replicate and renewed daily using fresh effluent. Test containers consisted of 250 ml plastic beakers filled to a volume of 200 ml. Daphnia pulex were transferred to new test solutions daily. Survival of D. pulex was recorded after 48 and 96 hours.

Fathead minnows were cultured at the Edison, NJ laboratory and acclimated to Great Miami River water following standard EPA protocols (Denny 1987). Acclimation of test organisms to Great

Miami River water was necessary to ensure that the assay would test the effects of FMPC effluent rather than the effects of the river water. Acclimation was initiated September 17, 1988 with water collected August 18, 1988, and was refreshed on September 23, 1988 with new Great Miami River water collected September 22, 1988. Twenty-nine day old fathead minnow juveniles were tested under daily renewal conditions for 96 hours. Test chambers consisted of 5.7 liter, all-glass aquaria filled to a volume of 3 liters. Each effluent concentration and control was run in duplicate, with ten minnows per replicate. Observations on survival, behavior, and locomotion of the organisms were made daily. After 96 hours of exposure, three minnows from each test chamber were measured and weighed (wet weight). Dissolved oxygen, pH, temperature, and conductivity were monitored daily in each replicate chamber.

3.3.2 Chronic Toxicity Tests

The green alga *Selenastrum capricornutum* was continuously exposed for 96 hours under static nonrenewal conditions to a dilution water control and the five concentrations of effluent. Three replicates were run of each concentration. Initial cell density for all concentrations and the controls was 10,000 cells/ml. Test chambers were held at 24°C for the duration of the test under continuous illumination of 400+/-40 foot-candles. Cells were counted after 48 and 96 hours with a Bright Line Neubauer hemacytometer.

Ceriodaphnia dubia (<24 hours old at test initiation) were continuously exposed for seven days under static renewal conditions to control water and the five concentrations of effluent. *Ceriodaphnia dubia* were individually exposed in 30 ml plastic cups containing 15 ml of test solution or control water with ten replicate beakers per concentration (ten animals total per concentration). Test animals were fed one ml of approximately 10^6

cells/ml of the green alga Ankistrodesmus falcatus daily (Horning and Weber 1985). Test beakers were placed in a water bath at a temperature of 25 ± 2°C with a photoperiod of 16 hours light: 8 hours dark and a light intensity of 50 to 100 foot-candles. Surviving Ceriodaphnia dubia were transferred daily with a large-bore pipette to newly prepared test solutions and fed. Live and dead (or immobilized) animals were counted daily after transfer of the parent organism to fresh test solutions. Reproduction was monitored by counting the number of offspring per parent daily. Temperature, dissolved oxygen, pH, and conductivity were measured daily on composite samples of newly prepared solutions of all test treatments as well as control water.

Chronic fathead minnow testing was conducted with newly hatched fry less than 12 hours old (Horning and Weber 1985). Acclimation procedures for fathead minnow eggs were the same as those for adult fish. Each effluent concentration and control was tested in duplicate. Test chambers consisted of one liter Tripour polypropylene beakers filled to a volume of one liter, containing ten fish. Survival and behavior were recorded daily, and test solutions replaced daily following these observations. After seven days, all surviving fish from each test chamber were carefully rinsed in deionized water, dried at 100°C, and weighed. Dissolved oxygen, conductivity, temperature, pH, alkalinity, and hardness were recorded daily.

3.3.3 Statistical Analyses

Statistical analyses of acute testing data were inappropriate, since there was no mortality in acute tests, as described in Chapter 4 below. Growth data from the chronic fathead minnow and algal tests and reproduction data from the Ceriodaphnia dubia test were analyzed using analysis of variance (Zar 1974). Each concentration mean was compared with the control mean using Dunnett's Procedure. Assumptions of normality and homogeneity of variances were tested with the Chi-Square Goodness of Fit Test and Hartley's and Bartlett's tests for homogeneity. Both tests are similar but Bartlett's test is not as sensitive to unequal sample sizes. A log transformation of the algal data was necessary to normalize the data.

Acute and chronic testing of FMPC effluent is continuing into 1990. A detailed report of methods and results will be prepared when all testing is completed.

3.4 THREATENED AND ENDANGERED SPECIES

3.4.1 Indiana Bat (Myotis sodalis)

The habitat within the study area (Figure 3-4) was visually surveyed from roads or from the Great Miami River during a float trip down the river section shown in Figure 3-4. Paddy's Run was surveyed by walking the section to be studied. All of the riparian habitat was classified by its potential use by the Indiana bat using a four category scheme as follows:

- Excellent — Mature woods with dead trees extending more than thirty yards beyond the stream edge on one or both banks
- Good — Mature woods on one or both banks but not extending far beyond the stream edge
- Fair — Immature woods on one or both banks
- Poor — No trees on one or both banks

Once habitats with a high potential for containing this species had been identified, landowners were approached and permission obtained to work these areas more intensively.

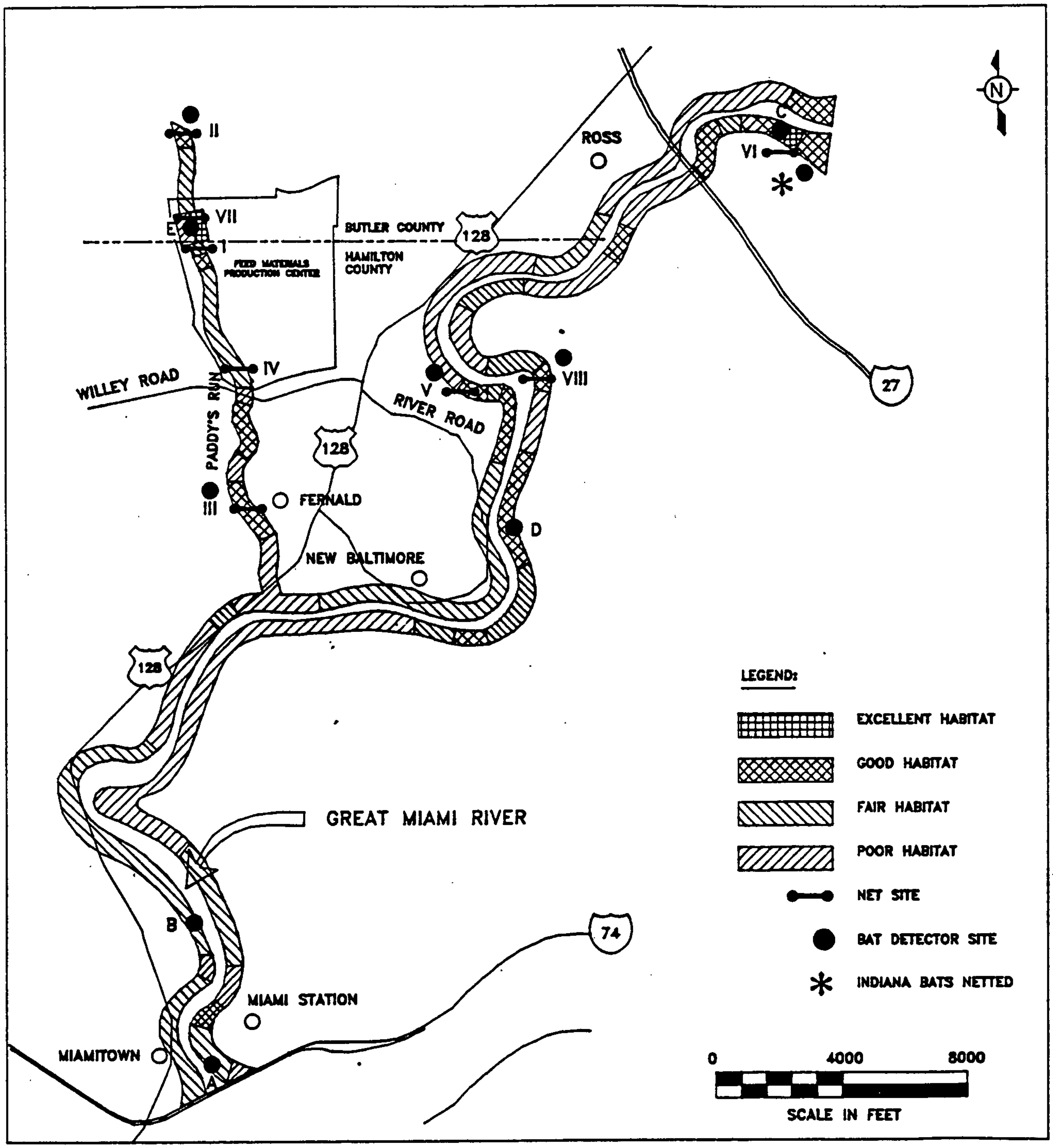


FIGURE 3-4. HABITAT EVALUATION AND SURVEY LOCATIONS FOR THE INDIANA BAT IN THE FMPC AND VICINITY

74

Bats were captured using mist nets suspended by ropes from trees or stretched on poles. Netting was conducted at eight sites (Figure 3-4) on 13 nights from June 24, 1987 to August 10, 1987. Net sites were assigned consecutive Roman numerals in the order in which they were used (Figure 3-4). Wherever possible, nets were placed over small streams or other flyways and positioned under overhanging vegetation so as to completely close the open space. Garden net was used in some cases to help seal openings around the nets. In some cases this positioning was impossible and nets were raised with considerable open space around them. Nets were tended from dusk until after midnight. Captured bats were identified to species, aged, sexed, temporarily marked for individual recognition, and released at the site of capture. Reproductive condition was also noted.

In some areas, netting was impractical due to limitations of the vegetation. In such areas, bat activity was monitored with a bat detector, an instrument which converts the bats' ultrasonic sounds to the human hearing range. This allows identification of bats to genus only. Bat activity was recorded in terms of bat passes, each pass being a series of echolocation pulses separated from other series by more than two seconds. The bat detector was used at five net sites (II, III, V, VI, and VIII) and five other sites (Figure 3-4) on 13 nights between June 24, 1987 and August 10, 1987.

3.4.2 Cave Salamander (*Eurycea lucifuga*)

An initial field reconnaissance to delineate areas with potential suitable cave salamander habitat was conducted by driving roads within the study area (Figure 3-5) and by talking with local residents. These areas were then explored on foot to identify potential habitat in detail and to search for individuals and populations of *Eurycea lucifuga*.

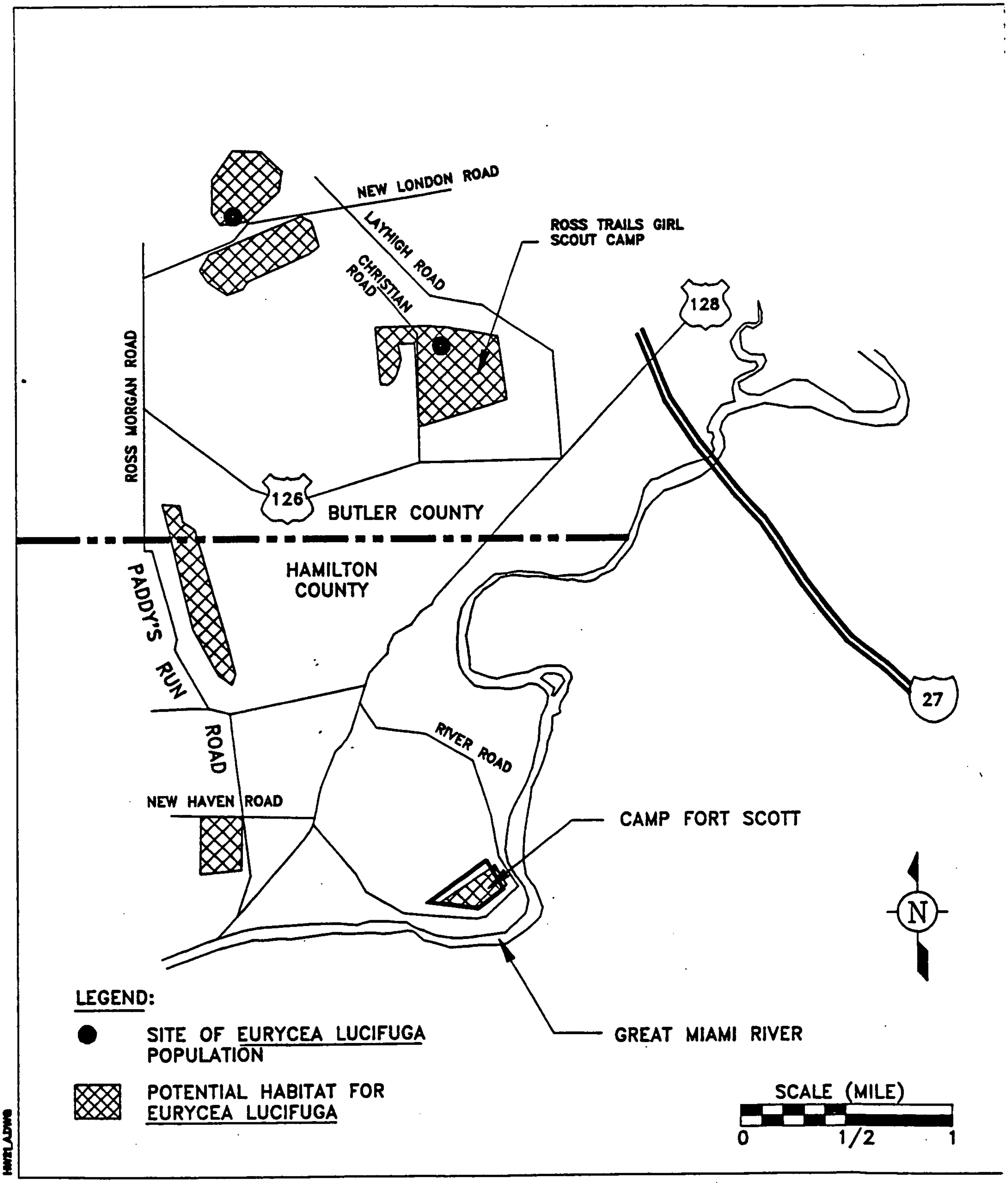


FIGURE 3-5. POPULATION LOCATIONS AND POTENTIAL HABITAT FOR THE CAVE SALAMANDER IN THE VICINITY OF THE FMPC

76

4.0 RESULTS AND DISCUSSION

4.1 BACKGROUND RADIONUCLIDE CONCENTRATIONS

All organisms are exposed to background radiation as a result of naturally occurring terrestrial radioactivity, solar and cosmic radiation, and radioactive fallout from nuclear weapons testing (NCRP 1975). Organisms on or in the vicinity of the FMPC are exposed to this background radiation in addition to potential exposure to radiation contributed by FMPC operations.

The background radionuclide concentrations in soil in the vicinity of the FMPC are presented in Table 4-1. A complete analysis of these data will be presented in the RI report for Operable Unit 5, Environmental Media. In addition, WMCO (1987b) collected soil and fertilizer samples at distances from 1.6 to 62.8 km (one to 39 miles) from the FMPC. Total uranium concentrations in soil ranged from 2.4 to 5.7 pCi/g (Appendix L), with no relationship between uranium concentration and distance from the FMPC. This suggests that the uranium concentration of 2.0 pCi/g in Table 4-1 may be a lower bound for background uranium concentrations in the vicinity of the FMPC. Uranium concentrations in fertilizer ranged from 0.03 to 121 pCi/g (Appendix L), indicating a potential contribution of fertilizer to uranium in soils and plants.

4.2 RADIOLOGICAL ANALYSES OF BIOLOGICAL SAMPLES

A total of 302 biological samples were collected for radionuclide analysis in 1987 and 1988. Sixty-three of these samples were archived, four contained insufficient mass for analysis, and 11 samples were not sent out for analysis. Therefore, a total of 224 samples was analyzed for radionuclides; of these, 15 samples were also analyzed for hazardous chemicals.

TABLE 4-1

BACKGROUND RADIONUCLIDE CONCENTRATIONS IN SOIL
IN THE VICINITY OF THE FMPC

Radionuclide	Concentration (pCi/g)
Total Uranium	2.0 pCi/g
Total Thorium	1.1 pCi/g
Cesium-137	0.6 pCi/g
Strontium-90	<0.5 pCi/g
Radium-226	<0.7 pCi/g
Radium-228	<0.9 pCi/g
Technetium-99	1.0 pCi/g

4.2.1 Garden Produce and Agricultural Crops

4.2.1.1 Indiana Control Area

Agricultural and garden produce samples were collected from three sites near Brookville, Indiana. A soil sample collected from a field at Site I1 had detectable levels of cesium-137, uranium-234, and uranium-238 (Table 4-2). Alfalfa from this site contained low but detectable quantities of strontium-90, uranium-234, uranium-235,-236, and uranium-238. Field corn samples contained radionuclide levels equal to those of the soil sample for cesium-137, uranium-234, and uranium-238 (Table 4-2).

Garden produce samples collected from Site I1 were okra, tomato, green pepper, and potatoes (Table 4-2). Soil from this garden contained detectable levels of cesium-137, uranium-234, and uranium-238. Of the vegetables, only tomatoes contained detectable levels of radionuclides.

Garden Site I2 was sampled for radionuclides in soil, tomatoes, green peppers, and potatoes. Soil contained detectable cesium-137, uranium-234, and uranium-238 (Table 4-2). Uranium-234 was detected in one sample of tomatoes and in potato peels. No other radionuclides were found in detectable levels in any samples from this site.

An agricultural field at Site I3 was sampled for field corn and soybeans. Soil from this site contained detectable levels of cesium-137, strontium-90, uranium-234 and uranium-238 (Table 4-2). Field corn and soybeans showed no detectable levels of radionuclides, and soybean husks had low levels of strontium-90 and uranium-234 (Table 4-2).

TABLE 4-2

INDIANA CONTROL AREA
RADIONUCLIDE CONCENTRATIONS IN
GARDEN PRODUCE, AGRICULTURAL CROPS, AND SOIL SAMPLES

		Radionuclide Type and Concentration (pCi/g)					
Sample	Location	Cs-137	Sr-90	U-234	U-235,-236	U-238	Sum of U Activity
Soil (field)	I1	0.3	<0.5	1.1	<0.6	1.0	2.1
Alfalfa	I1	<0.5	0.5	2.4	0.6	1.1	4.1
Field corn	I1	0.3	<0.5	1.1	<0.6	1.0	2.1
Soil (garden)	I1	0.3	<0.5	1.4	<0.6	1.2	2.6
Okra	I1	<0.4	<0.5	<0.6	<0.6	<0.6	--
Tomato	I1	<0.2	<0.5	2.5	<0.6	0.8	3.3
Green pepper	I1	<0.3	<0.5	<0.6	<0.6	<0.6	--
Potato (flesh)	I1	<0.2	<0.5	<0.6	<0.6	<0.6	--
Potato (peel)	I1	<0.2	<0.5	<0.6	<0.6	<0.6	--
Soil	I2	0.2	<0.5	2.4	<0.6	3.2	5.6
Tomato	I2	<0.2	<0.5	0.8	<0.6	<0.6	0.8
Tomato	I2	<0.4	<0.5	<0.6	<0.6	<0.6	--
Green pepper	I2	<0.3	<0.5	<0.6	<0.6	<0.6	--
Potato (flesh)	I2	<0.2	<0.5	<0.6	<0.6	<0.6	--
Potato (peel)	I2	<0.3	<0.5	2.7	<1.4	<1.4	2.7
Soil	I3	0.3	1.2	1.0	<0.6	1.3	2.3
Soybean	I3	<0.2	<0.5	<0.6	<0.6	<0.6	--
Soybean	I3	<0.2	<0.5	<0.6	<0.6	<0.6	--
Soybean (husk)	I3	<0.2	0.6	0.7	<0.6	<0.6	0.7
Field corn	I3	<0.2	<0.5	<0.6	<0.6	<0.6	--

Crops and garden produce sampled from the Indiana control area showed concentration ratios (CR) ranging from 0.14 to 1.95 (Table 4-3).

4.2.1.2 <u>FMPC and Vicinity</u>

Locally grown produce taken from a roadside stand about 1.8 km east of the FMPC (Site G7, Figure 3-1) did not contain detectable quantities of radionuclides (Table 4-4), with the exception of a composite sample of three tomatoes.

A soil sample from Site G1, located approximately 1.1 km (0.7 miles) north of the FMPC, contained detectable but low levels of cesium-137, uranium-234, and uranium-238 (Table 4-5). No detectable radionuclides were found in samples of green pepper, okra, tomato, and squash collected at this site. A cucumber sample had detectable uranium-234 and uranium-238 (Table 4-5). Concentration ratios for uranium-234 and -238 in the cucumber sample were 1.77 and 1.13, respectively.

Garden produce samples and a corresponding soil sample were collected from Site G2, approximately 2.1 km (1.3 miles) northeast of the FMPC (Figure 3-1). Detectable but low levels of cesium-137, strontium-90, uranium-234, and uranium-238 were found in the soil sample from this garden, but no detectable levels of any radionuclides were found in the vegetable samples collected (Table 4-5).

Three sites were sampled along Cincinnati-Brookville Road, northeast of the FMPC (Figure 3-1). Soil from a garden plot at Site G3 had detectable cesium-137, strontium-90, and uranium-234 (Table 4-5). Uranium-234 was found in tomato (CR = 1.00), okra (CR = 1.75), and green pepper samples (CR = 1.25). In addition, the okra sample contained detectable uranium-238. All other radionuclides analyzed were below detectable levels.

TABLE 4-3

INDIANA CONTROL AREA
TOTAL URANIUM CONCENTRATION RATIOS FOR
GARDEN PRODUCE AND AGRICULTURAL CROPS

Sample	Site	Concentration Ratio
Alfalfa	I1	1.95
Field corn	I1	1.00
Okra	I1	--[a]
Tomato	I1	1.57
Green pepper	I1	--
Potato flesh	I1	--
Potato peel	I1	--
Tomato	I2	0.14
Tomato	I2	--
Green pepper	I2	--
Potato flesh	I2	--
Potato peel	I2	0.48
Soybean	I3	--
Soybean	I3	--
Soybean husk	I3	0.30
Field corn	I3	--

[a] Radionuclide concentration below detectable limits; therefore, concentration ratio not calculated.

TABLE 4-4

POTENTIALLY AFFECTED AREA
RADIONUCLIDE CONCENTRATIONS IN
GARDEN PRODUCE FROM ROADSIDE STAND

Sample	Site	Radionuclide Type And Concentration (pCi/g)					
		Cs-137	Sr-90	U-234	U-235, -236	U-238	Sum of U Activity
Sweet corn	Roadside Stand	<0.2	<0.5	<0.6	<0.6	<0.6	--
Sweet corn	Roadside Stand	<0.2	<0.5	<0.6	<0.6	<0.6	--
Tomato	Roadside Stand	<0.5	<0.5	1.9	<0.6	0.7	2.6
Cantaloupe	Roadside Stand	<0.2	<0.5	<0.6	<0.6	<0.6	--

Site G4, located approximately 1.7 km (1.1 miles) from the FMPC, was an alfalfa field. A soil sample from this field contained detectable cesium-137, uranium-234, and uranium-238 (Table 4-5). Alfalfa from this site contained detectable levels only of uranium-234 (CR = 0.48).

A tomato garden and corn field were sampled at Site G5 (Figure 3-1). Soil from the tomato garden contained detectable uranium-234 and uranium-238 (Table 4-5), but no detectable radionuclides were found in tomatoes at this site. Soil from the corn field contained detectable strontium-90, uranium-234, and uranium-238, but no detectable radionuclides were found in either of two field corn samples.

A pumpkin field about 1.1 km (0.7 mile) directly east of the FMPC (Site G6) and a soybean field adjacent to and south of the pumpkin field were sampled. A soil sample from the soybean field contained detectable uranium-234 and uranium-238 (Table 4-5), but soybeans had no detectable radionuclides. Soil from the pumpkin field contained detectable cesium-137, strontium-90, uranium-234, and uranium-238. Two pumpkin samples contained detectable uranium-234 (Table 4-5), with CR = 0.41 and 0.24, respectively, and one sample contained uranium-238 (CR = 0.28).

Concentration ratios for total uranium in crops and garden produce samples from near the FMPC ranged from 0.23 to 2.75 (Table 4-6), with a mean of 1.03 (s.d = 0.91, n = 7). This was not significantly different from the mean CR for the Indiana control area samples of 0.91 (s.d. = 0.73, n = 6). There was thus no evidence at either the control sites or the FMPC sites that crops and produce were concentrating radionuclides relative to soil concentrations.

4.2.2 Vegetation

4.2.2.1 RI/FS Data

Excluding wetland sites, 95 samples of above- and belowground vegetation from 30 sites on the FMPC (Figure 3-2) were analyzed for radioisotopes during 1987. Variation in total uranium concentrations among sites was high (Table 4-7). Uranium concentrations by isotope in vegetation and soil are presented in Appendix M.

Total uranium ranged from nondetectable (<0.6 pCi/g) to 35.5 pCi/g and occurred at detectable levels in about 62 percent of the samples (Table 4-7). Uranium-234 and -238 accounted for approximately 47 and 51 percent, respectively, of the summed activity (Appendix M). Uranium-235 and -236, found in detectable levels in only nine percent of analyzed samples, accounted for about two percent.

With the exception of three samples, uranium isotope concentrations were consistently higher in roots than in aboveground samples, generally by a factor of at least two. The highest total uranium concentrations in vegetation, with the maximum at a site ranging from 17.3 to 35.5 pCi/g, were found at the following seven sites:

1. Site 28, approximately 30 m (100 feet) south of the fly ash pile (Figure 3-2);
2. Site 15, located east of the Production Area and adjacent to the sewage treatment plant (near the old incinerator site);
3. Site 12, located about 305 m (1,000 feet) directly east of the Production Area fence;
4. Site 10, located about 305 m (1,000 feet) east of the northeast corner of the Production Area;

TABLE 4-7

TOTAL URANIUM IN VEGETATION AND SOIL ON THE FMPC

	Total Uranium (pCi/g)					
Site	Soil	Grass Leaves	Grass Roots	Forb Leaves	Forb Roots	Other
1	4.2	<d.l.[a]	<d.l.	--[b]	--	--
2	4.5	--	--	<d.l.	1.7	--
3	14.0	<d.l.[c]	<d.l.[c]	--	--	--
4	9.9	1.8	3.7	4.9	2.9	--
	--	4.1	4.2	--	--	--
5	21.9	5.7	17.3	3.9	4.1	--
6	35.6	3.6	6.8	<d.l.	9.3	--
7	--	2.5	6.2	2.1	5.9	--
8	6.2	<d.l.	1.3	0.6	<d.l.	--
9	8.1	<d.l.	8.7	--	--	--
	6.8	--	--	--	--	--
10	--	15.7	26.6	4.1	1.5	--
	--	<d.l.[c]	3.2[c]	--	--	--
11	4.3	--	--	<d.l.	2.7	--
12	35.6	0.7	27.6	2.8	28.9	--
13	3.0	--	--	<d.l.	<d.l.	1.7[d]
	--	--	--	--	--	<d.l.[e]
	--	--	--	--	--	11.9[f]
14	--	--	--	6.4	23.6	<d.l.[f]
15	--	<d.l.	31.9	6.2	32.4	--
	--	<d.l.[c]	20.1[c]	--	--	--
16	7.6	<d.l.	2.8	1.6	4.0	--
17	32.4	<d.l.	5.6	--	--	0.6[g]
	--	--	--	--	--	<d.l.[h]
18	30.2	0.8	17.9	0.8	3.9	--
19	27.3	3.8	7.7	--	--	--
	--	3.4	8.9	--	--	--
20	13.3	2.9	4.3	--	--	--
21	11.4	5.5	<d.l.	--	--	--
22	10.0	--	--	<d.l.	2.3	--
23	5.3	<d.l.	<d.l.	--	--	--
24	9.1	1.9	3.1	--	--	--
25	5.9	0.6	5.7	--	--	--
26	6.9	<d.l.	<d.l.	--	--	--
27	2.7	<d.l.	<d.l.	--	--	--
28	32.5	2.6[c]	4.6[c]	2.2	35.5	--
	--	--	--	2.7	10.1	--
29	6.1	<d.l.	<d.l.	--	--	--
30	6.5	<d.l.	<d.l.	--	--	--
31	5.7	<d.l.	0.6	<d.l.	<d.l.	--

TABLE 4-7
(CONTINUED)

TOTAL URANIUM IN VEGETATION AND SOIL
ON THE FMPC

[a] <d.l. means that all isotopes of uranium were below detection limits
[b] Not sampled
[c] 1988 samples
[d] Onion leaves
[e] Onion bulbs
[f] Moss
[g] Mint leaves
[h] Pine needles

5. Site 14, about 230 m (750 feet) west of the southwest corner of the Production Area;

6. Site 18, about 152 m (500 feet) south of the southwest corner of the Production Area; and

7. Site 5, approximately 244 m (800 feet) north of the Production Area.

The total uranium concentration in soil at these sites ranged from 21.9 to 35.6 pCi/g (Table 4-7).

Sites with intermediate total uranium concentrations, with the maxmimum at a site ranging from 5.6 to 9.3 pCi/g, were:

1. Site 6, located about 244 m (800 feet) northeast of the Production Area;

2. Site 7, approximately 396 m (1,300 feet) northeast of the Production Area;

3. Site 19, approximately 144 m (400 feet) southeast of the Production Area;

4. Site 25, about 366 m (1200 feet) southeast of the Production Area;

5. Site 17, about 244 m (800 feet) southwest of the Production Area; and

6. Site 9, located approximately 549 m (1,800 feet) west of the Production Area near Waste Pit 5.

The total uranium concentration in soil at these sites ranged from 5.9 to 35.6 pCi/g (Table 4-7).

Lower, but detectable levels of uranium were observed at Sites 2, 4, 20, 24, 22, 16, 11, and 8, with the maxmimum at a site ranging from 1.3 to 4.9 pCi/g and soil concentrations ranging from 4.3 to 13.3 pCi/g (Table 4-7).

Total soil uranium was a good predictor of the concentration of uranium in grass roots ($r = 0.655$, $n = 14$, $P < 0.05$). The correlation of soil uranium with forb root uranium was at the margin of statistical significance ($r = 0.629$, $n = 10$, $0.05 < P < 0.10$). There was no correlation between soil uranium concentrations and grass or forb leaf uranium concentrations.

Cesium-137 and strontium-90 concentrations were consistently low, occurring at detectable levels in only 27 percent of the aboveground and 7 percent of the belowground samples, respectively (Tables 4-8 and 4-9). Cesium-137 in vegetation ranged from nondetectable (<0.2 to <0.8 pCi/g) to 1.4 pCi/g (Table 4-8). Only a few sites in 1987 exhibited detectable concentrations above the background for soils (Table 4-1): Sites 7, 10, 12, 18, and 25. Cesium-137 occurred in detectable levels in aboveground plant parts at only three sites: 4, 6 and 14 (Table 4-8). For those sites with detectable cesium-137 in soil and in grass roots, the soil concentration was a good predictor of the grass root concentration ($r = 0.638$, $n = 15$, $P < 0.01$). The other possible soil-vegetation pairs were too few to calculate correlations.

Detectable levels of strontium-90, ranging from 0.6 to 0.9 pCi/g, occurred in vegetation only at Sites 5, 6, 7, 12, 18, and 28 (Table 4-9). Strontium-90 concentrations in soil ranged from nondetectable (<0.5 pCi/g) to 2.5 pCi/g. There was insufficient data to calculate the correlation of soil strontium levels with vegetation levels. There was no significant difference between strontium-90 concentrations in soils where strontium was detected in vegetation versus soils where strontium was not detected in vegetation. The mean concentration of strontium-90 in soils where strontium was detectable in vegetation was 0.86 pCi/g (s.d. = 0.33, n = 5), and the mean concentration of strontium-90 in soils where strontium was not detected in vegetation was 1.10 pCi/g (s.d. = 0.33, n = 15).

TABLE 4-8

CESIUM-137 IN VEGETATION AND SOIL ON THE FMPC

	Cesium-137 (pCi/g)					
Site	Soil	Grass Leaves	Grass Roots	Forb Leaves	Forb Roots	Other
1	0.8	<0.3	0.3	--[a]	--	--
2	0.5	--	--	<0.2	<0.2	--
3	1.0	<0.2[b]	1.2[b]	--	--	--
4	0.6	<0.2	<0.5	0.4	<0.3	--
	--	<0.3	<0.3	--	--	--
5	0.8	<0.3	<0.2	<0.2	<0.4	--
6	1.6	0.4	<0.5	<0.2	0.2	--
7	--	<0.5	0.8	<0.2	<0.6	
	--	--	0.3	--	--	--
8	0.7	<0.3	0.6	<0.3	<0.2	--
9	<0.2	<0.3	<0.2	--	--	--
	<0.2	--	--	--	--	--
10	--	<0.2	1.4	<0.2	<0.7	--
	--	<0.2[b]	1.2[b]	--	--	--
11	<0.2	--	--	<0.2	<0.2	--
12	0.9	<0.3	0.9	<0.2	0.8	--
13	<0.2	--	--	<0.4	<0.3	<0.7[c]
	--	--	--	--	--	0.3[d]
	--	--	--	--	--	<0.2[e]
14	--	--	--	<0.3	<0.3	0.6[e]
15	--	<0.3	<0.3	<0.3	0.3	--
	--	<0.2[b]	1.2[b]	--	--	--
16	0.4	<0.2	0.3	<0.2	<0.3	--
17	1.0	<0.2	0.6	--	--	<0.2[f]
	--	--	--	--	--	<0.2[g]
18	1.2	<0.8	1.0	<0.6	<0.8	--
19	0.7	<0.2	0.6	--	--	--
	--	<0.3	0.4	--	--	--
20	0.8	<0.4	0.5	--	--	--
21	0.9	<0.4	<0.2	--	--	--
22	0.7	--	--	<0.3	<0.3	--
23	0.3	<0.2	0.3	--	--	--
24	1.1	<0.3	0.6	--	--	--
25	0.7	<0.2	0.8	--	--	--
26	0.8	<0.3	0.3	--	--	--
27	<0.2	<0.3	<0.2	--	--	--
28	0.8	<0.2[b]	0.9[b]	<0.2	<0.4	--
	--	--	--	<0.3	<0.4	--
29	0.8	<0.2	0.6	--	--	--
30	0.5	<0.3	0.4	--	--	--
31	0.8	<0.2	0.4	<0.3	<0.2	--

TABLE 4-8
(Continued)

CESIUM-137 IN VEGETATION AND SOIL
ON THE FMPC

[a] Not sampled
[b] ~~Lost in analysis~~
[c] 1988 samples
[d] Onion leaves Onion bulbs
[e] Moss
[f] Mint leaves
[g] Pine needles

TABLE 4-9

STRONTIUM-90 IN VEGETATION AND SOIL
ON THE FMPC

	Strontium-90 (pCi/g)					
Site	Soil	Grass Leaves	Grass Roots	Forb Leaves	Forb Roots	Other
1	<0.5	<0.5	<0.5	--[a]	--	--
2	2.5	--	--	<0.5	<0.5	--
3	LIA[b]	<0.5[c]	<0.5[c]	--	--	--
4	LIA	<0.7	<0.5	<0.5	<0.7	--
	--	<0.7	<0.5	--	--	--
5	1.4	<1.5	<0.8	0.7	0.6	--
6	0.9	<0.8	<0.7	<0.5	0.7	--
7	--	<0.7	<0.5	<0.5	<1.4	--
	--	--	0.8	--	--	--
8	1.5	<0.5	<0.5	<0.5	<0.5	--
9	0.6	<1.5	<0.5	--	--	--
	0.5	--	--	--	--	--
10	--	<0.5	<0.5	<0.6	<0.5	--
	--	<0.5[c]	<0.5[c]	--	--	--
11	<0.5	--	--	<0.5	<0.5	--
12	0.6	<0.6	<0.5	0.9	<0.5	--
13	<0.5	--	--	<1.0	<0.6	<1.9[d]
	--	--	--	--	--	<0.5[e]
	--	--	--	--	--	<0.5[f]
14	--	--	--	<0.6	<0.5	<1.4~~[e]~~[f]
15	--	<0.5	<0.5	<0.5	<0.5	--
	--	<0.5[c]	<0.5[c]	--	--	--
16	1.3	<0.5	<0.2	<0.6	<0.6	--
17	0.6	<0.5	<0.5	--	--	<0.5~~[f]~~[g]
	--	--	--	--	--	<0.5[h]
18	0.8	0.6	<0.5	<0.5	<0.5	--
19	0.9	<0.7	<0.5	--	--	--
	--	<0.9	<0.5	--	--	--
20	1.5	<0.6	<0.5	--	--	--
21	<0.5	<1.2	<0.5	--	--	--
22	<0.5	--	--	<0.5	<0.5	--
23	<0.5	<0.5	<0.5	--	--	--
24	1.1	<0.5	<0.5	--	--	--
25	0.8	<0.5	<0.5	--	--	--
26	0.8	<0.7	<0.5	--	--	--
27	1.6	<0.5	<0.5	--	--	--
28	0.6	<0.5[c]	<0.5[c]	<0.5	<0.5	--
	--	--	--	0.6	<0.6	--
29	1.2	<0.8	<0.4	--	--	--
30	0.6	<0.8	<0.5	--	--	--
31	1.0	<0.5	<0.5	<0.6	<0.5	--

TABLE 4-9
(CONTINUED)

STRONTIUM-90 IN VEGETATION AND SOIL
ON THE FMPC

[a] Not sampled
[b] Lost in analysis
[c] 1988 samples
[d] Onion leaves
[e] Onion bulbs
[f] Moss
[g] Mint leaves
[h] Pine needles

Sites 10, 15, and 28 were resampled in 1988 because of elevated uranium levels in samples collected from these locations in 1987. Samples collected during 1988 were analyzed for technetium-99 in addition to the previously discussed radionuclides. Of the three sites sampled, detectable levels of technetium-99 occurred only at Site 15 (Figure 3-2), with 5.5 and 1.2 pCi/g in grass leaves and grass roots, respectively. No uranium, strontium, or technetium was detected in grass leaves and roots collected from Site 3 in 1988, despite detectable cesium and uranium in soil samples collected from that site in 1987 (Tables 4-7, 4-8, 4-9). Cesium-137 was detected in grass roots from Site 3 in 1988 (Table 4-8).

No uranium was detected in grass leaves collected from Site 10 during 1988, compared to 15.7 pCi/g in 1987 (Table 4-7). Grass roots at this site contained only 1.6 pCi/g each of uranium-234 and uranium-238 in 1988 (Appendix M), while 1987 samples had 12.9 and 13.7 pCi/g of uranium-234 and uranium-238, respectively. Cesium-137 and strontium-90 levels were very similar between years for grass leaves and roots (Tables 4-8 and 4-9).

Results between years were more similar for Site 15. Uranium isotopes were not detectable in grass leaves for either year. Total uranium decreased from 31.9 in 1987 to 20.1 pCi/g in 1988 (Table 4-7). Strontium-90 was not found in detectable levels in either year (Table 4-9), and cesium-137 increased from less than detectable levels in 1987 to 1.2 pCi/g in grass roots in 1988 (Table 4-8).

Radionuclide levels in samples from Site 28 were similar between years for aboveground plant parts. However, total uranium was lower in 1988 than in 1987 for belowground plant parts (Table 4-7). Given the variation in radionuclide levels in the vegetation samples, the differences between 1987 and 1988 do not indicate a significant trend.

4.2.2.2 WMCO Data

The vegetative portions of grasses and forbs were collected by NLO and WMCO as part of their routine environmental monitoring (NLO 1985, WMCO 1986, 1987b), from various locations on and around the FMPC. These vegetation data for total uranium as a function of distance from the FMPC are presented in Appendix N.

The highest concentrations of uranium were generally found in soil and vegetation samples collected within one kilometer of the FMPC, and decreased by one to two orders of magnitude with increasing distance from the FMPC. The total uranium range was 0.09-7.09 pCi/g in 1984, 0.09-2.34 pCi/g in 1985, and 0.06-4.29 pCi/g in 1986 (Appendix N). These ranges are smaller than the range for RI/FS data (Table 4-7), but the uranium levels reported by NLO and WMCO for vegetation closest to the FMPC are consistent with the data presented in Table 4-7.

4.2.2.3 Discussion

RI/FS sampling in 1987 was designed to measure radionuclide accumulation in both grass and forb components of the pasture vegetation and to discriminate between root and shoot accumulation. The mean concentration of total uranium isotopes in grassland vegetation sampled in 1987 was 7.84 pCi/g (s.d. = 9.19, n = 61). The mean total uranium concentrations of both grass (3.79 pCi/g., s.d. = 3.80, n = 14) and forb leaves (mean = 3.19 pCi/g, s.d. = 1.93, n = 12) were lower than their corresponding root components. Grass roots accumulated a mean of 9.69 pCi/g (s.d. = 9.38, n = 20), while forb roots accumulated a mean of 11.25 pCi/g (s.d. = 12.25, n = 15). There was no significant difference in uranium concentrations between grass leaves and forb leaves or between grass roots and forb roots, although forb leaf uranium concentrations were significantly less variable than grass leaf concentrations (F-test, $P < 0.05$). The standard deviations of all samples were high, reflecting the highly variable distribution of uranium in areas sampled at the FMPC.

The mean CR for uranium in forb leaves (mean = 0.16, s.d. = 0.15, n = 8; Table 4-10) was similar to that for grasses (mean = 0.19, s.d. = 0.14, n = 12). The CR for uranium in grass roots (mean = 0.49, s.d. = 0.34, n = 17) was similar to that for forb roots (mean = 0.44, s.d. = 0.30, n = 11). Root and leaf mean concentration ratios were thus within one order of magnitude of each other and were less than one. This indicates that on average grasses and forbs accumulated similar amounts of uranium, and both groups accumulated uranium to levels lower than those in the soil in which they were growing. RI/FS sampling thus provides no evidence that pasture plants in the vicinity of the FMPC are concentrating uranium from the soil.

No evidence was found of biomagnification of soil uranium by vegetation on the FMPC. However, using guidelines published by the Nuclear Regulatory Commission (NRC), grassland vegetation samples from the FMPC contained higher levels of the three uranium isotopes than would be expected from soil background. Multiplying the NRC guideline concentration ratio of 0.017 for uranium isotopes (Till and Meyer 1983) by the FMPC background uranium soil concentration of 2.0 pCi/g (Table 4-1) gives an expected background level of 0.034 pCi/g in pasture vegetation. This number is 20 times lower than the detection limits for RI/FS data (Appendix M), and similar to the lower bound of the WMCO data (Appendix N). However, the NRC CR is only one tenth the CR's calculated for RI/FS data (Tables 4-3, 4-6, and 4-10), including the Indiana control area data.

Ten-fold differences in CR's between studies are common and may be due to a number of variables. These variables include soil chemistry, differential accumulation within plant organs and tissues, plant species phenology, growth conditions, agricultural

TABLE 4-10

TOTAL URANIUM CONCENTRATION
RATIOS FOR VEGETATION ON THE FMPC[a]

Site	Grass Leaves	Grass Roots	Forb Leaves	Forb Roots
1	--[b]	--	ns[c]	ns
2	ns	ns	--	0.38
3	ns	ns	ns	ns
4	0.18	0.37	0.50	0.29
	0.~~14~~41	0.42	ns	ns
5	0.26	0.79	0.18	0.19
6	0.10	0.19	--	0.26
7	ns	ns	ns	ns
8	--	0.21	0.10	--
9	--	1.07	ns	ns
	--	1.28	ns	ns
10	ns	ns	ns	ns
11	ns	ns	--	0.63
12	0.02	0.49	0.08	0.81
13	ns	ns	--	--
14	ns	ns	ns	ns
15	ns	ns	ns	ns
16	--	0.37	0.21	0.53
17	--	0.17	ns	ns
18	0.03	0.59	0.03	0.13
19	0.14	0.28	ns	ns
	0.13	0.33	ns	ns
20	0.22	0.32	ns	ns
21	0.48	--	ns	ns
22	ns	ns	--	0.23
23	--	--	ns	ns
24	0.21	0.34	ns	ns
25	0.10	0.97	ns	ns
26	--	--	ns	ns
27	--	--	ns	ns
28	ns	ns	0.07	1.09
	ns	ns	0.08	0.31
29	--	--	ns	ns
30	--	--	ns	ns
31	--	0.11	--	--

[a] Plant: soil concentration ratio (CR), calculated from 1987 data in Table 4-7.

[b] -- CR not calculated because uranium not detected in soil or vegetation sample or both.

[c] ns Not sampled. Where all four columns show not sampled, soil was not sampled at the site.

methods, and experimental design (Romney et al. 1981, Boikat et al. 1985). Soil characteristics that cause much of the variability in CR's include texture, clay content, dominant clay mineral, cation exchange capacity, exchangeable calcium and potassium, pH, and organic matter (Ng 1982).

Vegetation analyses included cesium-137 and strontium-90 in addition to uranium. Cesium is considered an analogue for potassium in uptake studies, and the potential for cesium-137 entering terrestrial food chains is high (Reichle et al. 1970). The NRC guideline concentration ratio (vegetation:soil) for cesium is 1.0×10^{-2}. The maximum cesium-137 soil concentration observed on the FMPC was 1.6 pCi/g (Site 6, Table 4-8). This would yield an anticipated Cs-137 concentration in vegetation of 1.6×10^{-2} pCi/g, which is below the detection limits in Table 4-8. Cesium-137 was detected in vegetation at 17 of the 23 sites at which it was detected in soil. The mean CR for these sites (Table 4-11) was 0.68 (s.d. = 0.26, n = 20 (Some sites had more than one CR). RI/FS sampling thus provides no evidence that vegetation in the vicinity of the FMPC is concentrating cesium-137 at levels higher than the soil in which it is growing.

Strontium-90 releases into the environment are important because strontium-90 mimics the behavior of calcium in ecosystems. Ng (1982) reported a range of mean concentration ratios (vegetation:soil) from 7.1×10^{-3} to 2.2×10^{0} and an NRC guideline of 1.7×10^{-2}. Only five sites had calculatable CRs for strontium-90 (Table 4-12). The mean of 0.83 (s.d. = 0.39, n = 6) provides no evidence that vegetation in the vicinity of the FMPC is concentrating strontium-90 from the surrounding soil.

TABLE 4-11

CESIUM-137 CONCENTRATION RATIOS
FOR VEGETATION ON THE FMPC[a]

Site	Grass Leaves	Grass Roots	Forb Leaves	Forb Roots
1	--[b]	0.38	ns[c]	ns
2	ns	ns	--	--
3	ns	ns	ns	ns
4	--	--	0.67	--
	--	--	--	--
5	--	--	--	--
6	0.25	--	--	0.13
7	ns	ns	ns	ns
8	--	0.86	--	--
9	--	--	ns	ns
10	ns	ns	ns	ns
11	ns	ns	--	--
12	--	1.00	--	0.89
13	ns	ns	--	--
14	ns	ns	ns	ns
15	ns	ns	ns	ns
16	--	0.75	--	--
17	--	0.60	ns	ns
18	--	0.83	--	--
19	--	0.86	ns	ns
	--	0.57	ns	ns
20	--	0.63	ns	ns
21	--	--	ns	ns
22	ns	ns	--	--
23	--	1.00	ns	ns
24	--	0.54	ns	ns
25	--	1.14	ns	ns
26	--	0.38	ns	ns
27	--	--	ns	ns
28	ns	ns	--	--
29	--	0.75	ns	ns
30	--	0.80	ns	ns
31	--	0.50	--	--

[a] Plant: soil concentration ratio (CR), calculated from 1987 data in Table 4-8.
[b] -- CR not calculated because cesium-137 not detected in soil or vegetation sample or both.
[c] ns Not sampled. Where all four columns show not sampled, soil was not sampled at the site.

TABLE 4-12

STRONTIUM-90 CONCENTRATION RATIOS
FOR VEGETATION OF THE FMPC[a]

Site	Sample	CR
5	forb leaves	0.50
	forb roots	0.43
6	forb roots	0.78
12	forb leaves	1.50
18	grass leaves	0.75
28	forb leaves	1.00

[a] Plant: soil concentration ratio (CR), calculated from data in Table 4-9. Strontium-90 in all samples not shown was below detection limits in soil or vegetation or both (see Table 4-9).

4.2.3 Mammals

No detectable radionuclides were found in mammal samples, except for uranium in a composite sample of small mammal organs collected adjacent to Waste Pit 5 (Table 4-13). The composite carcass sample from which the organs were taken had no detectable radionuclides.

4.2.4 Wetland Habitat

4.2.4.1 RI/FS Data

No detectable radionuclides were found in samples of algae from Sites PR-1 and PR-2A, with the exception of 0.9 pCi/g strontium-90 at Site PR-1 (Table 4-14).

At Site 6A (Figure 3-2), only uranium-238 was found above detection limits, for a cattail leaf sample (Table 4-14). No other radionuclides were found above detection limits at Site 6A.

Soil from Site 9A contained detectable strontium-90, uranium-234, and uranium-238 (Table 4-14). Vegetation had detectable uranium-234, uranium-235, -236, and uranium-238. Concentrations of uranium were the highest at this site (Table 4-14), with concentration ratios of 0.09 in one cattail leaf sample, 0.39 in cattail roots, and 1.92 in grass roots. The concentration ratio for U-234 in grass roots was 1.97. Grass leaves collected from site 9A in 1988 had detectable technetium-99 (Table 4-14), but all other radionuclides were below detectable levels. Grass roots collected during 1988 had lower, but still detectable levels of uranium-234 and uranium-238 than 1987 samples.

Cattail leaves at Site 9B contained detectable, but low levels of uranium-234 and uranium-238 (Table 4-14). The root samples taken from this pond did not contain detectable quantities of radionuclides.

TABLE 4-13

RADIONUCLIDES IN MAMMAL TISSUE FROM THE FMPC

			Radionuclide Type And Concentration (pCi/g)						
						U-235			
Sample	Type	Site	Cs-137	Sr-90	Tc-99[a]	U-234	U-236	U-238	Sum of U Activity
Opossum	Muscle	N. Pine Plantation	<0.2	<0.5		<0.2	<0.2	<0.2	---
Opossum	Organs	N. Pine Plantation	<0.2	<0.5		<0.6	<0.6	<0.6	---
Opossum	Muscle[c]		<0.3	<0.5	<1.0	<0.6	<0.6	<0.6	---
Cottontail	Muscle[c]		<0.7	<0.5	<0.9	<0.6	<0.6	<0.6	---
Small mammal[b] (Composite)	Carcasses	Waste Pit Number 5	<0.2	<0.1		<0.6	<0.6	<0.6	---
Small mammal[b] (Composite)	Organs	Waste Pit Number 5	<1.1	<2.5		8.3	1.1	8.6	18.0
Small mammal[b,c]	Carcasses		<0.2	<0.5	ISFA[d]	<0.6	0.6	<0.6	---
Deer	Kidney[c]		<0.2	<0.5	<0.9	<0.6	0.6	<0.6	---
Deer	Liver[c]		<0.2	<0.5	<0.9	<0.6	<0.6	<0.6	---

[a]Technetium - 99 analyzed for 1988 samples only.
[b]Composite small mammal samples of white-footed mouse and short-tailed shrew.
[c]1988 samples.
[d]Insufficient sample for analysis.

TABLE 4-14

RADIONUCLIDE CONCENTRATIONS IN WETLAND
PLANTS ON THE FMPC

Sample	Site	Radionuclide Type And Concentration (pCi/g)						
		Cs-137	Sr-90	Tc-99[a]	U-234	U-235, -236	U-238	Sum of U Activity
Algae[b]	PR1	<0.2	0.9	<0.9	<0.6	<0.6	<0.6	---
Algae[b]	PR2A	<0.2	<0.5	<0.9	<0.6	<0.6	<0.6	---
Cattail leaf	6A	<0.6	<0.9		<0.6	<0.6	0.8	0.8
Cattail root	6A	<0.2	<0.9		<0.6	<0.6	<0.6	---
Sedge leaf	6A	<0.2	<0.7		<0.6	<0.6	<0.6	---
Sedge leaf	6A	<0.2	<1.3		<0.6	<0.6	<0.6	---
Soil	9A	<0.2	0.6		3.9	<0.6	12.4	16.3
Cattail leaf	9A	<0.3	<0.5		<0.6	<0.6	<0.6	---
Cattail leaf	9A	<0.2	<0.5		0.7	<0.6	0.7	1.4
Cattail root	9A	<0.3	<0.5		2.6	<0.6	3.8	6.4
Grass leaf	9A	<0.3	<0.6		<0.6	<0.6	<0.6	---
Grass root	9A	<0.2	<0.5		7.7	1.3	22.3	31.3
Grass leaves[b]	9A	<0.2	<0.5	1.9	<0.6	<0.6	<0.6	---
Grass roots[b]	9A	<0.2	<0.5	<0.9	0.9	<0.6	4.2	5.1
Cattail leaf	9B	<0.4	<1.0		1.4	<0.6	1.9	3.3
Cattail root	9B	<0.2	<0.5		<0.6	<0.6	<0.6	---
Cattail leaf	19A	<0.4	<1.0		<0.6	<0.6	<0.6	---
Cattail root	19A	<0.2	<0.5		1.6	<0.6	2.2	3.8

[a] Technetium-99 analyzed for 1988 samples only.
[b] 1988 sample.

No radionuclides were detected in cattail leaves collected from Site 19A, the drainage ditch near the main parking lot (Figure 3-2, Table 4-14). However, low but detectable levels of uranium-234 and uranium-238 were present in cattail root samples (Table 4-14).

4.2.4.2 Discussion

Maslov et al. (1966) classified uranium in aquatic systems as biotrophic, i.e., tending to concentrate in the living portion of the system as opposed to remaining in solution or precipitating out into the mineral or sediment load. Biotrophic absorption and adsorption in the aquatic environment has been observed for algae, higher aquatic and wetland plants, invertebrates, and fish (Reichle et al. 1970, El-Shinawy and Abdel-Malik 1980, Swanson 1985). Evidence presented in Table 4-14 suggests that wetland vegetation on the FMPC may accumulate uranium in this manner.

Kulikov and Molchanova (1982) suggested that upon the decay of aquatic or semiaquatic plant species, most of the radionuclides present are complexed into dead organic matter. As a result, radionuclides are introduced into detritus and sediments, and are then available for ingestion by a variety of aquatic species, including macroinvertebrates and fish. Data on radionuclide concentrations in macroinvertebrates and fish in the vicinity of the FMPC are presented below.

4.2.5 Benthic Macroinvertebrates

4.2.5.1 Paddy's Run

Benthos samples collected in 1988 from PR-1, located above the influence of the FMPC on Paddy's Run, contained no detectable radionuclides (Table 4-15). Benthos samples from PR-2 contained detectable uranium-234 and uranium-238. Crayfish analyzed from PR-2 and PR-3 also contained detectable uranium-234 and uranium-238. Crayfish collected from PR-4 had detectable uranium-234.

TABLE 4-15

RADIONUCLIDES IN BENTHIC MACROINVERTEBRATES FROM PADDY'S RUN

Site	Radionuclide Type And Concentration (pCi/g)						
	Cs-137	Sr-90	Tc-99[a]	U-234	U-235, -236	U-238	Sum of U Activity
PR1[b]	<0.2	<0.5	<0.9	<0.6	<0.6	<0.6	--
PR-2	<2.0	<3.7		3.6	<1.5	2.8	6.4
PR-2 (Crayfish)	<1.94	<1.2		3.5	<0.9	0.9	4.4
PR-3 (Crayfish)	<4.00	<2.6		3.6	<1.1	1.5	5.1
PR-4 (Crayfish)	<0.24	<1.8		1.5	<0.6	<0.6	1.5

[a] Technetium - 99 analyzed for 1988 samples only.
[b] 1988 sample.

The detection of above-background levels of radioactivity in Paddy's Run sediments (WMCO 1987b) indicates that radionuclides are present, and the data in Table 4-15 suggest that these contaminants may be entering aquatic food chains. Two crayfish species, Orconectes rusticus and Orconectes sloanii are known to occur in Paddy's Run (Appendix J). If they are consumed, crayfish may transport contaminants off site to the local human population.

4.2.5.2 Great Miami River

Benthic macroinvertebrate samples were collected from all four sites on the Great Miami River (Figure 3-3), but sufficient biomass for radionuclide analysis was collected only at GMR-2 and GMR-4 (Table 4-16). Benthos samples from both GMR-2, the background (upstream) station, and GMR-4, just below the FMPC effluent line, had detectable uranium-234 and uranium-238. A crayfish sample collected from GMR-2 in 1988 contained no detectable radionuclides, including technetium-99.

Although the presence of detectable uranium in these samples suggests a potential route to fish populations, this was not demonstrated in fish collected from the Great Miami River (Table 4-18) in this study.

4.2.6 Fish

Results of radionuclide analyses of fish samples, divided by location, are presented in Tables 4-17 through 4-19.

4.2.6.1 Paddy's Run

One composite sample of minnows from Site PR-1, analyzed for radionuclides in 1988, had no detectable levels of any radionuclide (Table 4-17). Creek chubs from Site PR-2 had detectable uranium-234 and -238 (Table 4-17). No detectable radionuclides were found in creek chubs, white suckers, and bluegills from Site PR-3. Detectable but low levels of uranium-234 were found in a white

TABLE 4-16

RADIONUCLIDES IN BENTHIC MACROINVERTEBRATES FROM THE GREAT MIAMI RIVER

Site	Radionuclide Type And Concentration (pCi/g)						
	Cs-137	Sr-90	Tc-99[a]	U-234	U-235, -236	U-238	Sum of U Activity
GMR-2[b]	<0.2	<1.1	<0.9	<0.6	<0.6	<0.6	--
GMR-2	<0.6	<1.7		1.8	<0.8	0.9	~~6.4~~ 2.7
GMR-4	<2.1	<4.7		3.4	<2.2	3.1	6.5

[a] Technetium - 99 analyzed for 1988 samples only.
[b] 1988 sample.

TABLE 4-17

RADIONUCLIDES IN FISH FROM PADDY'S RUN

Sample	Site	Radionuclide Type And Concentration (pCi/g)						
		Cs-137	Sr-90	Tc-99[a]	U-234	U-235,-236	U-238	Sum of U Activity
Minnow[b]	PR-1	<0.2	<0.5	<1.6	<0.6	<0.6	<0.6	--
Minnow	PR-2	<0.42	<0.5	<0.6		<0.6	<0.6	--
White sucker	PR-2	<0.20	<0.5		LIA[c]	LIA	LIA	--
Creek chub	PR-2	<1.90	<0.7		1.0	<0.6	0.7	1.7
Creek chub	PR-3	<0.17	<0.5		<0.6	<0.6	<0.6	--
White sucker	PR-3	<0.22	<0.5		<0.6	<0.6	<0.6	--
Bluegill	PR-3	<0.19	<0.5		<0.6	<0.6	<0.6	--
White sucker	PR-4	<0.41	<0.5		0.6	<0.6	<0.6	0.6
Creek chub	PR-4	<0.24	<0.5		<0.6	<0.6	<0.6	--
Bluegill	PR-4	<1.23	<3.32		2.4	<1.1	1.3	3.7

[a] Technetium - 99 analyzed for 1988 samples only.

[b] 1988 sample.

[c] LIA = Lost in analysis

sucker sample from Site PR-4 (Table 4-17), and a bluegill sample from this site had detectable uranium-234 and uranium-238.

The presence of detectable levels of radionuclides in fish at Sites PR-2 and PR-4 as well as in invertebrates from Sites PR-2, PR-3, and PR-4 (Table 4-15) suggests that organisms in Paddy's Run may be exposed to contaminants from the FMPC, possibly via runoff from the site.

4.2.6.2 Great Miami River

RI/FS Data

No detectable radionuclides were found in fish samples from any site on the Great Miami River (Table 4-18).

WMCO Data

WMCO (1986) reported that uranium concentrations in fish from the Great Miami River ranged from 0.02 pCi/g to 0.78 pCi/g between 1984 and 1986 (Appendix O). There was no apparent relationship between uranium concentrations in fish and location on the Great Miami River. Differences in concentrations among years were statistically insignificant. Most of the fish uranium concentrations reported by WMCO (Appendix O) were below the detection limits of the present study. There is thus no reason to expect any difference in conclusions based on these two data sets.

4.2.6.3 FMPC Pond

Bluegill and creek chub samples from the FMPC pond (Figure 3-2) had no detectable levels of radionuclides, but a sample of white suckers had low but detectable levels of uranium-234 and uranium-238 (Table 4-19).

TABLE 4-18

RADIONUCLIDES IN FISH FROM THE GREAT MIAMI RIVER

Sample	Site	Radionuclide Concentration (pCi/g)					
		Cs-137	Sr-90	U-234	U-235,-236	U-238	Sum of U Activity
Gizzard shad	GMR-1	<0.3	<0.5	<0.6	<0.6	<0.6	--
Gizzard shad	GMR-1	<0.2	<0.5	<0.6	<0.6	<0.6	--
Channel catfish	GMR-1	<0.2	<0.5	<0.6	<0.6	<0.6	--
Minnow	GMR-1	<0.2	<0.5	<0.6	<0.6	<0.6	--
Catfish (fillets)	GMR-1	<0.7	<0.5	<0.6	<0.6	<0.6	--
Catfish (fillets)	GMR-1	<0.3	<0.5	<0.6	<0.6	<0.6	--
Catfish (bones and entrails)	GMR-1	<0.2	<0.5	<0.6	<0.6	<0.6	--
Gizzard shad	GMR-2	<0.2	<0.5	<0.6	<0.6	<0.6	--
Freshwater drum	GMR-2	<0.2	<0.5	<0.6	<0.6	<0.6	--
Smallmouth bass	GMR-2	<0.3	LIA[a]	LIA	LIA	LIA	--
Gizzard shad	GMR-3	<0.2	<0.5	<0.6	<0.6	<0.6	--
Green sunfish	GMR-3	<0.3	<0.5	<0.6	<0.6	<0.6	--
Longear sunfish	GMR-3	<0.3	<0.5	<0.6	<0.6	<0.6	--
Gizzard shad	GMR-4	<0.2	<0.5	<0.6	<0.6	<0.6	--
Gizzard shad	GMR-4	<0.2	<0.5	<0.6	<0.6	<0.6	--
Minnow	GMR-4	<0.2	<0.5	<0.6	<0.6	<0.6	--

[a] LIA = Lost in Analysis

TABLE 4-19

RADIONUCLIDES IN FISH FROM THE FMPC POND

Sample	Cs-137	Sr-90	U-234	U-235,236	U-238	Sum of U Activity
	Radionuclide Type And Concentration (pCi/g)					
Bluegill	<0.2	<0.5	<0.6	<0.6	<0.6	--
White sucker	<0.2	<0.5	0.7	<0.6	1.0	1.7
Creek chub	<0.2	<0.5	<0.6	<0.6	<0.6	--

4.2.6.4 Discussion

Fish may be exposed to radionuclides in aquatic habitats and may be affected by absorption through the skin, gills, and gastrointestinal tract; adsorption to external organs; and ingestion. Ingestion is considered the most important uptake route for radionuclides in fish (Davis and Foster 1958, Reichle et al. 1970). Additionally, contact with sediments directly or through the ingestion of food organisms was found to be an important source of uranium and radium in fish tissue (Swanson 1983). While fish gills represent important ion exchange sites, they are not thought to take up radionuclides in significant amounts (Reichle et al. 1970). However, fish collected during RI/FS sampling did not have radionuclide concentrations higher than macroinvertebrates (Tables 4-17, 4-18, 4-19). There is thus no evidence of biomagnification of radionuclides by fish in Paddy's Run or the Great Miami River. A detailed study to test the potential for bioaccumulation of uranium by fish caged in the Great Miami River and Paddy's Run is being conducted in 1990 to test this conclusion.

4.3 CHEMICAL ANALYSES OF BIOLOGICAL SAMPLES

4.3.1 Priority Pollutant Base-, Neutral-, and Acid-Extractable Organics

Table 4-20 presents results of analyses for selected priority pollutant organics for 15 biological samples from the FMPC. None of these compounds were detected in any sample.

4.3.2 Pesticides and PCBs

PCB concentrations were determined for the PCBs aroclor -1260, -1254, -1221, -1248, -1016, -1232, and -1242. Pesticides analyzed were chlordane and 4,4-DDT. No detectable pesticides or PCBs were found in any samples (Table 4-21).

TABLE 4-20

PRIORITY POLLUTANT BASE/NEUTRAL/ACID ORGANIC ANALYSES
OF BIOLOGICAL SAMPLES FROM THE FMPC, 1988

Sample Type	Location	Organic Concentrations (mg/kg)							
		Anthracene	Butylbenzyl-Phthalate	Chrysene	Fluoranthene	Phenanthrene	Pyrene	2-Nitrophenol	4-Nitrophenol
Grass leaves	3	20000u	20000u	20000u	20000u	20000u	20000u	20000u	100000u
Grass roots	3	10000u	10000u	10000u	10000u	10000u	10000u	10000u	50000u
Grass leaves	15	10000u	10000u	10000u	10000u	10000u	10000u	10000u	50000u
Grass roots	15	10000u	10000u	10000u	10000u	10000u	10000u	10000u	50000u
Grass leaves	10	10000u	1800jB	10000u	10000u	10000u	10000u	10000u	50000u
Grass roots	10	10000u	1300jB	10000u	10000u	10000u	10000u	10000u	50000u
Grass leaves	9A	10000u	2000j	10000u	10000u	10000u	10000u	10000u	50000u
Grass roots	9A	10000u	1000j	10000u	10000u	10000u	10000u	10000u	50000u
Grass leaves	28	20000u	20000u	20000u	20000u	20000u	20000u	20000u	100000u
Grass roots	28	10000u	1600j	10000u	10000u	10000u	10000u	10000u	50000u
Minnows	PR-1	20000u	20000u	20000u	20000u	20000u	20000u	20000u	20000u
Small mammal (carcass)	28	10000u	10000u	10000u	10000u	10000u	10000u	10000u	50000u
Cottontail (muscle)	28	10000u	10000u	10000u	10000u	10000u	10000u	10000u	50000u
Deer (kidney)		1000u	1000u	1000u	1000u	1000u	1000u	1000u	5000u
Deer (liver)		10000u	10000u	10000u	10000u	10000u	10000u	10000u	50000u

113

u indicates compound was not detected
j indicates estimated detection level
B indicates compound found in blank sample

TABLE 4-21

PESTICIDE/PCB ANALYSES OF BIOLOGICAL SAMPLES
FROM THE FMPC, 1988

Sample Type	Location	Aroclor-1260	Aroclor-1254	Aroclor-1221	Aroclor-1016	Aroclor-1232	Aroclor-1242	Chlordane	4,4-DDT
		Pesticide/PCB (Aroclor) Concentrations (mg/kg)							
Grass leaves	3	800u	800u	800u	800u	800u	800u	800u	400u
Grass roots	3	800u	800u	800u	800u	800u	800u	800u	400u
Grass leaves	15	800u	800u	800u	800u	800u	800u	800u	400u
Grass roots	15	800u	800u	800u	800u	800u	800u	800u	400u
Grass leaves	10	800u	800u	800u	800u	800u	800u	800u	400u
Grass roots	10	800u	800u	800u	800u	800u	800u	800u	400u
Grass leaves	9A	800u	800u	800u	800u	800u	800u	800u	400u
Grass roots	9A	800u	800u	800u	800u	800u	800u	800u	400u
Grass leaves	28	800u	800u	800u	800u	800u	800u	800u	400u
Grass roots	28	800u	800u	800u	800u	800u	800u	800u	400u
Minnows	PR-1	800u	800u	1400u	800u	800u	800u	800u	400u
Small mammal (carcass)	28	800u	800u	800u	800u	800u	800u	800u	400u
Cottontail (muscle)	28	800u	800u	800u	800u	800u	800u	800u	400u
Deer (kidney)		800u	800u	800u	800u	800u	800u	800u	400u
Deer (liver)		800u	800u	800u	800u	800u	800u	800u	400u

u indicates compound was not detected

4.3.3 <u>Metals</u>

Table 4-22 presents the results of metals analyses for 15 biological samples from the FMPC.

Arsenic levels ranged from a low of less than detectable levels in a grass root sample from wetland Site 9A (Figure 3-2) to 20 mg/kg in a deer liver sample. Little variation occurred among samples, regardless of location or type.

Aluminum concentrations ranged from less than detectable levels (4 mg/kg) in a cottontail muscle sample and a deer liver sample to 10,600 mg/kg in a grass root sample from Site 10, about 305 meters (1000 feet) east of the northeast corner of the Production Area. In general, plant tissues had considerably higher concentrations of aluminum than animal tissues (Table 4-22). Among the ten paired grass leaf and root samples, three had root concentrations higher than leaves by two to three orders of magnitude. Two of the grass leaf and root pairs had similar concentrations.

Barium levels were generally much lower in animal samples than in plant samples, ranging from less than detectable levels (0.2 mg/kg) in deer organ and cottontail muscle samples to 59.8 mg/kg in a grass sample from Site 10 (Table 4-22). Concentrations were consistently higher in grass root samples than in the corresponding leaf samples.

Cadmium concentrations were consistently low, ranging from less than detectable levels (0.5 mg/kg) in 11 of 15 samples, to 4.2 mg/kg in a composite minnow sample from Site PR-1 on Paddy's Run, located on the FMPC but above any potential FMPC contaminant influence. Grass roots generally had higher cadmium concentrations than grass leaves (Table 4-22).

Lead concentration patterns were similar to those of cadmium. Concentrations ranged from less than detectable levels (3 mg/kg) in 11 of 15 samples to 12 mg/kg in a grass root sample from Site 10 (Table 4-22). Grass root samples generally had higher lead concentrations than grass leaf samples. Animal tissues had no detectable lead.

Mercury concentrations ranged from less than detectable levels (0.1 mg/kg) in deer organ and cottontail muscle tissue, to 67.1 mg/kg in a grass leaf sample from Site 28, just below the fly ash pile. There was no obvious relationship between above- and belowground concentrations of mercury in plants (Table 4-22).

Silver concentrations were less than detection limits (0.5 mg/kg) in all samples (Table 4-22).

Vanadium concentrations were consistent with most other metals, ranging from less than detection limits (1 mg/kg) for nine of 15 samples, including all animal tissues to 20 mg/kg in a plant root sample from Site 10 (Table 4-22). Grass root concentrations were consistently higher than those in grass leaves.

Zinc concentrations ranged from 4.4 mg/kg in a grass leaf sample from Site 9A to 115.0 mg/kg in a grass root sample from Site 15, adjacent to the sewage treatment plant. Zinc concentrations were consistently higher in grass root samples than grass leaf samples. Plant concentrations were similar to animal concentrations.

4.3.4 <u>Fluoride and Sulfate</u>

4.3.4.1 <u>RI/FS Data</u>

Fluoride and sulfate concentrations are presented in Table 4-23. Fluoride levels ranged from 15 mg/kg in a grass root sample from Site 28 to 2,400 mg/kg in a deer liver sample. Fluoride levels

TABLE 4-23

FLUORIDE AND SULFATE ANALYSES OF BIOLOGICAL SAMPLES FROM THE FMPC, 1988

Sample Type	Site	Concentrations (mg/kg) Fluoride	Sulfate
Grass leaves	3	330	2400
Grass root	3	620	1300
Grass leaves	15	340	830
Grass roots	15	15	80
Grass leaves	10	80	1600
Grass roots	10	58	240
Grass leaves	9A	210	320
Grass roots	9A	50u	830
Grass leaves	28	720	110
Grass roots	28	15	67
Minnows	PR1	1400	830
Small mammal (carcass)	28	710	1700
Cottontail (muscle)	28	540	160
Deer (kidney)	-	160	60
Deer (liver)	-	2400	140

u means below detection limits

TABLE 4-25

EFFECT OF FMPC EFFLUENT ON REPRODUCTION
OF THE CLADOCERAN *CERIODAPHNIA DUBIA*, SEPTEMBER 1988

Effluent Concentration, %	Total Offspring Produced per Adult	Total Offspring as % of Control
Control[a]	24.3	100
6.25	22.5	93
12.5	20.6	85
25.0	16.5[b]	68
50.0	14.4[b]	59
100.0	13.5[b]	56

[a] Water collected from the Great Miami River at the Ross bridge.
[b] Significantly different from the control at the $P<0.05$ level. $N=10$ for each concentration.

being rated excellent, 23 percent good, 54 percent fair, and 19 percent poor. Habitat along Paddy's Run was considered marginal for Indiana bats by Multerer (1986). Most of the good habitat identified in the present study was in the northern portion of the study area near Ross, Ohio.

Foraging ranges of the Indiana bat have been reported to extend from one half to three quarters of a mile from the colony tree (Humphrey et al. 1977, Cope et al. 1978). The capture of significant numbers of this species at Banklick Creek indicates the presence of an active colony nearby, although the colony itself was not found. Further, the presence of this species within the study area means that all habitat classified as good must be considered to have high potential for containing these bats, even though none were captured except at this site.

4.5.2 Cave Salamander (Eurycea lucifuga)

The cave salamander was not found within the FMPC boundaries, but individuals were found near New London Road north of the FMPC and within the boundaries of the Ross Trails Girl Scout Camp northeast of the FMPC (Figure 3-5). Marginal cave salamander habitat was identified along Paddy's Run within the FMPC. Good to excellent habitat occurs offsite in the vicinity of New London Road, New Haven Road, Ross Trails Girl Scout Camp, and Camp Fort Scott.

Habitats that are likely to support the cave salamander have suitable cover, e.g., limestone slabs, caves, fallen trees, and moist conditions which generally occur in heavily wooded ravines. Small springs enhance the available habitat, since they are a permanent water and moisture source. Ohio populations of the cave salamander are limited to Butler, Hamilton, and Adams counties.

Although populations were found at only one site during this study (Figure 3-5), the exceptionally dry conditions during the study (summer 1988) may have caused the salamanders to retreat within the ground. It is therefore possible that investigation during wetter periods would reveal populations of cave salamanders in the area identified as potential habitat (Figure 3-5).

4.5.3 Other Species

The cobblestone tiger beetle (Cicendela margipennis), which is under review by the U.S. Fish and Wildlife Service for possible inclusion in threatened or endangered species lists, was found during the Indiana bat survey on a gravel bar in the Great Miami River two miles west southwest of the bridge at New Baltimore, Ohio. Three specimens where captured and identified by Dr. William H. Buskirk, Professor of Biology, Earlham College. These specimens were placed in his private collection. Dr. Buskirk estimated the total population on that one bar to be 30 to 40 individuals. One other bar was surveyed but no beetles of this species were found.

5.0 CONCLUSIONS

The objectives of the Biological Resources Sampling Plan were (1) to determine whether any radiological or hazardous substances released to the FMPC environs were transferred to wildlife habitats, including wetlands, or to agricultural produce, and (2) to determine if any such transfers represent a significant hazard to human beings or to threatened or endangered wildlife species.

Local produce had uranium concentrations no higher than those in produce from a control area, indicating that local produce is probably not a significant pathway for human exposure to uranium derived from FMPC operations. Exposure to other FMPC-derived radionuclides through agricultural products does not appear to be significant. Uranium concentrations in soil and vegetation exhibited high spatial variability. The pattern of higher uranium concentrations in soil and vegetation to the north and east of the FMPC correlates with the direction of prevailing winds and suggests an atmospheric pathway for radionuclide transport to these areas. Concentration ratios (plant:soil) in forage plants were always less than one, indicating that plants are not concentrating uranium at levels higher than those in the soil in which they are growing. Biomagnification of uranium by vegetation is therefore not a likely route for exposure of animals or humans to uranium.

Data on radionuclide transfer to wildlife species are limited. Uranium concentrations in the one small mammal sample in this study were high, and could indicate a potential exposure pathway to raptors feeding on the FMPC. However, their wide feeding ranges should limit their exposure to radionuclides from the FMPC. Uranium concentrations in doves and quail, a potential exposure pathway for human beings, have not yet been determined. Sampling of these two game species for radionuclides, both on site and in nearby offsite areas, is recommended to address this question.

Aquatic organisms could be exposed to FMPC-derived radionuclides in wetlands, in Paddy's Run, and in the Great Miami River. Fish from these habitats are in turn a potential exposure pathway for wildlife and humans. Uranium concentrations in macroinvertebrates and fish from the Great Miami River were low or below detection limits. Detectable levels of radionuclides were found in soil and grass at wetland site 9A on the FMPC and in macroinvertebrates and fish in Paddy's Run. This suggests that fish, birds, and mammals feeding on aquatic organisms in Paddy's Run may be exposed to uranium through the aquatic food chain. The limited data do not allow a test of this hypothesis. However, a study of uranium bioaccumulation by caged fish placed in Paddy's Run and the Great Miami River is being conducted in 1990 and will address this question in detail.

Toxicity tests of FMPC effluent show only slight toxicity at effluent concentrations forty times the concentration of effluent once it enters the Great Miami River. Testing continuing in 1990 will provide further information on any potential toxicity of FMPC effluent. In addition, tests will be conducted in 1990 to determine whether contaminants leachable from soils and sediments on the FMPC could be toxic to aquatic organisms.

There is no evidence that threatened or endangered species are currently at risk from radionuclides or hazardous substances released by the FMPC.

No evidence was found that humans or wildlife on and near the FMPC are being exposed to hazardous substances other than radionuclides.

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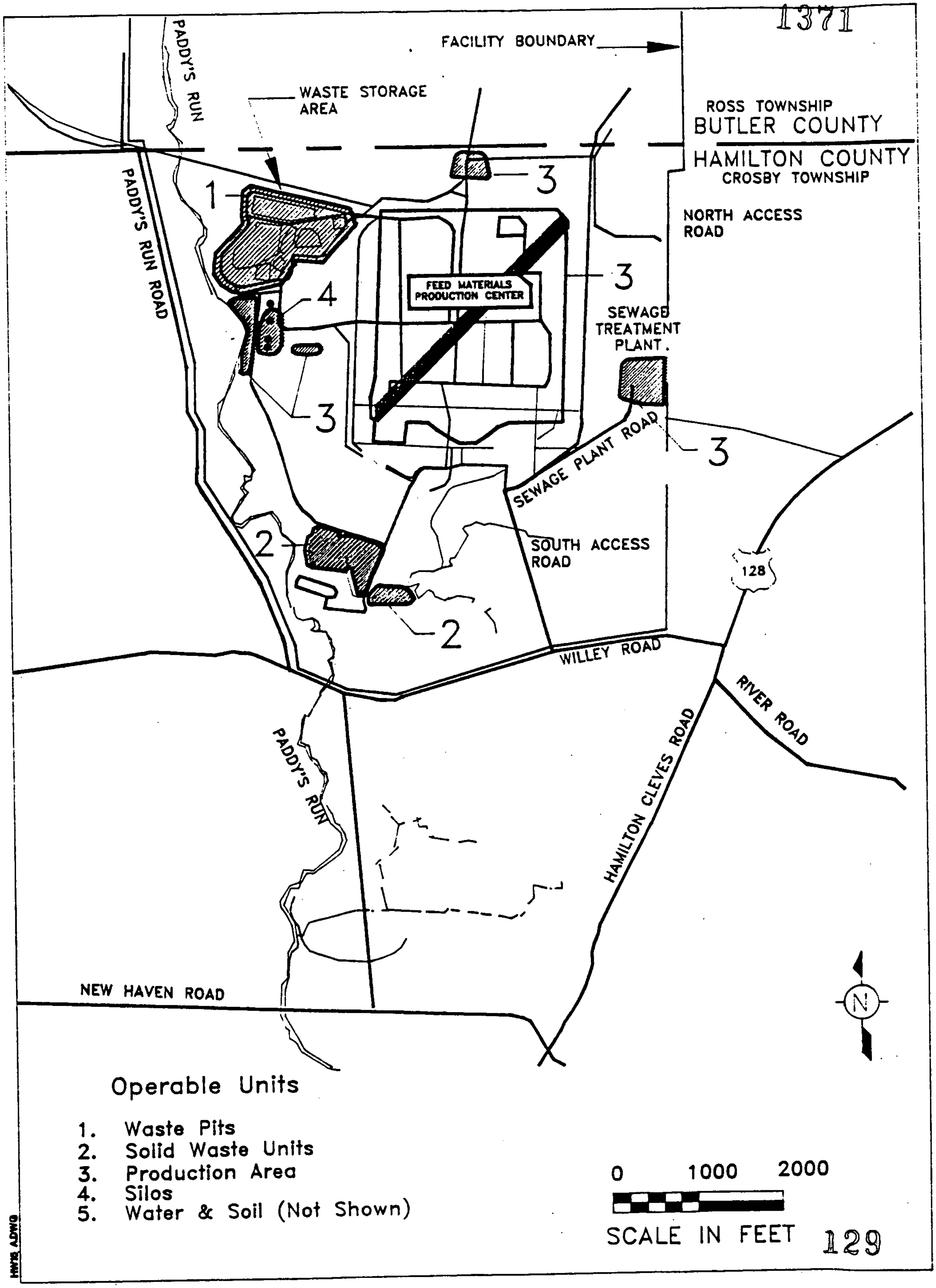
APPENDIX A

DESCRIPTION OF OPERABLE UNITS FOR THE RI/FS AT THE FEED MATERIALS PRODUCTION CENTER

For purposes of the RI/FS, the FMPC site has been segmented into five operable units (Figure A-1) that comprise the total scope of the remedial action program. Operable units are distinctive groupings of facilities and environmental media that will enable DOE to expedite remedial actions on the highest priority operable units while awaiting necessary data and related analysis on other operable units. These operable units are: 1) Waste Storage Area; 2) Solid Waste Areas; 3) Production Facilities and Suspect Areas; 4) Special Facilities (Silos); and 5) Environmental Media.

Operable Unit 1, Waste Storage Areas, includes the six waste pits, the burn pit, and the clear well, located in the northwestern portion of the FMPC. The waste pits are no longer in use. Waste Pits 1, 2, 4, and 6 were mostly used for disposal of dry radioactive waste. Waste Pits 3 and 5 were used for treatment of liquid wastes. The burn pit was used to burn waste materials, including pyrophoric and reactive chemicals, oils, and other combustible low-level radioactive material. Use of the Burn Pit was discontinued in 1986. The clear well was used as a collection and settling basin for liquid overflow from Pit 5 and for runoff from the waste storage area; since shutdown of the process flow to Pit 5 in early 1987, use of the clear well has been limited to collecting surface stormwater runoff from the waste pit area. The intent of the remedial action is to stabilize, isolate or treat the waste and any associated cover materials to prevent the release or migration of contaminants to the environment. The remedial action alternatives include, but are not limited to:

- No Action
- In-Place Isolation of Waste from the Environment
- In-Place Stabilization of Waste



129

FIGURE A-1 OPERABLE UNITS LOCATION MAP

- Waste Removal, Treatment/Stabilization and OnSite Disposal
- Waste Removal, Treatment/Stabilization and OffSite Disposal

Operable Unit 2, Solid Waste Units, includes the north and south lime sludge ponds, active fly ash pile, abandoned fly ash pile and southfield area, and sanitary landfill. The lime sludge ponds, located in the waste storage area, are settling and drying beds for alkaline sludges produced from the treatment of the raw water supply to the FMPC. The fly ash piles contain fly ash from the onsite coal-fired boiler plant and are located southwest of the Production Area. In the past, the abandoned fly ash pile was sprayed with oils contaminated with uranium to control dust. The southfield area, located at the northern edge of the abandoned fly ash pile, was used to dispose of uranium-contaminated construction rubble. The sanitary landfill is located northeast of the waste storage area and served as the disposal area for waste paper, rags, and other types of solid sanitary wastes from the production facilities. It is intended that the solid waste units that represent a potential source of contamination to the environment be part of a remedial action. The solid waste units are distinguished by the presence of large volumes of solid waste materials but only small amounts of chemical or radioactive wastes that were mixed with the solid wastes during the years of operation. Consequently, it is expected that the remedial alternatives for these units will involve standard and widely practiced technologies of waste stabilization or isolation and runoff control. The remedial action alternatives include, but are not limited to:

- No Action
- In-Place Isolation
- In-Place Stabilization of Waste

- Waste Removal, Reduction, Onsite Disposal
- Waste Removal, Reduction, Offsite Disposal

Operable Unit 3, Facilities and Suspect Areas, includes specific areas within the production area that will be identified as the facilities testing program proceeds. The following is a listing of the additional suspect areas outside of the production area currently being considered under Operable Unit 3:

- Fire training area
- Incinerator area (east of the production area)
- Area near the flag pole
- K-65 Slurry line trench
- Several rubble mounds
- Area near the proposed D&D building
- Trench adjacent to the proposed D&D building

A variety of remedial actions is being considered for the elements of the operable unit: groundwater collection and treatment or disposal; soil capping or removal and disposal; liquid waste containment, or removal and disposal; repair and upgrade of facilities; and replacement or removal with disposal.

Operable Unit 4, Special Facilities, includes the K-65 silos (Silos 1 and 2), the metal oxides silo (Silo 3), and an empty silo (Silo 4). The silos are major inactive waste storage structures at the FMPC. The K-65 silos (1 and 2) hold waste residues from the processing of pitchblende ore. These residues contain uranium and high concentrations of radium and other radioactive decay products as well as many other metals. The two hazards associated with the silos are the release of radioactive radon gas (and direct gamma radiation) and the possible failure of the silos. Silo 3 contains calcined waste from past refinery operations. The remedial action alternatives include, but are not limited to:

- No Action
- In-Place Isolation of Waste from the Environment
- In-Place Stabilization of Waste
- Waste Removal, Stabilization, Onsite Disposal
- Waste Removal, Separation of Waste Components, Onsite Disposal by Component
- Waste Removal, Stabilization, Offsite Disposal
- Waste Removal, Separation of Waste Components, Offsite Disposal by Component

Operable Unit 5, Environmental Media, includes those environmental media that represent pathways and/or environmental receptors presently or potentially affected by the release of radionuclides or chemicals from the FMPC:

- All surface soils
- Great Miami Buried Valley Aquifer
- Great Miami River
- Paddy's Run
- Stormwater outfall ditch
- Flora and fauna
- Ambient air

A wide variety of alternatives is being evaluated for each potentially affected area. The alternatives include but are not limited to:

- No Action
- Groundwater Pumping and Reinjection for Pathway Control
- Groundwater Pumping with Direct Discharge to Surface Waters

- Groundwater Pumping With Treatment Prior to Discharge
- Groundwater Use Restrictions
- Groundwater Alternate Water Supply
- Groundwater Use Restrictions With Treatment at User Location
- Soil/Sediment Stabilization
- Soil/Sediment Capping
- Soil/Sediment Removal and Disposal
- Flora/Fauna Removal and Disposal

APPENDIX B

PLANT SPECIES OBSERVED ON THE FMPC[a]

SCIENTIFIC NAME	COMMON NAME	HABITAT[b]	OCCURRENCE/[c] ABUNDANCE
Equisetaceae			
Equisetum arvense	Common horsetail	R	Sp-Su[d]/R
Pinaceae			
Picea excelsa	Norway Spruce	P	Y/R*
Pinus nigra	Austrian pine	P	Y/A*
Pinus strobus	White pine	P	Y/A*
Cupressaceae			
Juniperus virginiana	Eastern red cedar	W	Y/R
Poaceae			
Bromus ciliatus	Fringed brome	W	Sp/R
Bromus inermis	Smooth brome	P	Sp/R*
Bromus commutatus	Hairy brome	R	Sp/R*
Bromus sp.	Brome grass	IG,F,P,R	Sp/A
Festuca rubra	Red fescue	IG,F,P,W,R	Su/A*
Festuca elatior	Meadow fescue	IG,P,W,R	Su,Sp[e]/A*
Festuca obtusa	Nodding fescue	P,W,R	Sp/O
Festuca sp.	Fescue	IG,F,P,R	Sp/A
Poa annua	Annual bluegrass	W	Sp/R*
Poa compressa	Canada bluegrass	W,R	Sp/O*
Poa pratensis	Kentucky bluegrass	IG,F,P,W,R	Sp,Su/A*
Poa sp.	Bluegrass	IG,F,P,W,R	Su,Sp/C
Dactylis glomerata	Orchard grass	IG,P	Sp/C*
Agropyron sp.	Wheatgrass	W	Sp/O
Elymus virginicus	Virginia wild-rye	R	Sp/R
Elymus villosus	Hairy wild-rye	R	Sp/R
Hystrix patula	Bottlebrush	P,R	Sp/R
Agrostis alba	Redtop	IG,P,W	Su/R
Agrostis stoloniferous var. major	Redtop	IG,P,W	Su/O*
Phleum pratense	Timothy-grass	IG,F,P	Su/O*
Digitaria filiformis	Slender crabgrass	R	Su/R
Digitaria sp.	Crabgrass	IG	Sp/O
Enchinochloa crusgalli	Barnyard grass	W,R	Su/R*
Setaria sp.	Bristly foxtail	R	Su/R
Unknown grasses		IG,P,R	Sp/O
Cyperaceae			
Carex conjuncta	Sedge	R	Sp/R
Carex scoparia	Broom sedge	P	Sp/R
Carex amphibola	Narrowleaf sedge	P	Sp/R
Carex blanda	Woodland sedge	W	Sp/O
Carex sp.	Sedge	IG,F,P,W,R	Sp,Su/O

APPENDIX B (continued)

PLANT SPECIES OBSERVED ON THE FMPC[a]

SCIENTIFIC NAME	COMMON NAME	HABITAT[b]	OCCURRENCE/[c] ABUNDANCE
Commelinaceae			
Commelina communis	Dayflower	R	Su/R*
Juncaceae			
Juncus tenuis	Slender rush	IG,W	Su/R
Liliaceae			
Hemerocallis fulva	Day lilly	W	Sp/R*
Allium canadense	Wild onion	IG,P,W,R	Sp,Su/R
Smilacina racemosa	False Solomon's seal	W,R	Sp/R
Trillium sessile	Sessile trillium	W,R	Sp/R
Smilax glauca	Cat briar	R	Su/O
Smilax sp.	Green briar/Cat briar	R	Sp-Su/R
Salicaceae			
Populus deltoides	Eastern cottonwood	F,W,R	Y/A
Salix nigra	Black willow	R	Y/R
Salix sp.	Willow	R	Y/R
Juglandaceae			
Juglans nigra	Black walnut	W,R	Y/C
Carya cordiformis	Bitternut hickory	W,R	Y/R
C. laciniosa	Shellbark hickory	W	Y/C
C. tomentosa	Mockernut hickory	W	Y/R
C. ovata	Shagbark hickory	R	Y/R
Betulaceae			
Betula sp.	Birch	R	Y/R
Fagaceae			
Quercus bicolor	Swamp white oak	R	Y/R
Q. prinus	Chestnut oak	W	Y/O
Q. prinoides	Chinquapin oak	R	Y/R
Q. imbricaria	Shingle oak	W,R	Y/C
Q. borealis	Northern red oak	W	Y/C
Ulmaceae			
Ulmus americana	American elm	F,W,R	Y/A
U. rubra	Slippery elm	W,R	Y/O
Celtis occidentalis	Hackberry	W,R	Y/C
Moraceae			
Maclura pomifera	Osage-orange (Hedge-apple tree)	R	Y/O

APPENDIX B (continued)

PLANT SPECIES OBSERVED ON THE FMPC[a]

SCIENTIFIC NAME	COMMON NAME	HABITAT[b]	OCCURRENCE/[c] ABUNDANCE
Urticaceae			
<u>Urtica</u> <u>dioica</u>	Nettle	R	Sp-Su/O*
<u>U.</u> <u>procera</u>	Nettle	R	Su/O
<u>Bohemeria</u> <u>cylindrica</u>	False nettle	F,R	Sp/R
<u>Pilea</u> <u>pumila</u>	Clearwood	P,W,R	Su/C
Aristolochiaceae			
<u>Asarum</u> <u>canadense</u>	Wild ginger	W,R	Sp,Su/R
Polygonaceae			
<u>Rumex</u> <u>crispus</u>	Curly dock	R	Sp/R*
<u>Rumex</u> <u>obtusifolius</u>	Bitter dock	W	Su/R*
<u>Rumex</u> sp.	Dock	W,R	Sp,Su/R
<u>Polygonum</u> <u>persicaria</u>	Lady-thumb	W,R	Su/R*
<u>Polygonum</u> <u>hydropiperoides</u>	Mild water-pepper, Smartweed	W,R	Su/R
<u>Polygonum</u> <u>virginiana</u> (<u>Tovara</u> <u>virginiana</u>)	Jumpseed Tovara/Jumpseed	W	Su/R
<u>Polygonum</u> <u>cilinode</u>	Climbing buckwheat Bindweed	P,R	Su/R
<u>Polygonum</u> sp.	Smartweed	R	Su/R
Chenopodiaceae			
<u>Chenopodium</u> <u>album</u>	Lamb's quarters	R	Sp/R*
Portulacaceae			
<u>Claytonia</u> <u>virginiana</u>	Spring beauty	W,R	Sp/R
Caryophyllaceae			
<u>Stellaria</u> <u>media</u>	Common chickweed	IG,F,P,W,R	Sp/C*
<u>Cerastium</u> <u>vulgatum</u>	Mouse-ear chickweed	IG	Sp/R*
<u>Saponaria</u> <u>officinalis</u>	Bouncing bet/soapwort	R	Sp-Su/R*
Ranunculaceae			
<u>Ranunculus</u> <u>abortivus</u>	Kidney leaf buttercup	W,R	Sp/R
<u>Ranunculus</u> sp.	Buttercup	IG,F,P,W,R	Sp/O
Berberidaceae			
<u>Podophyllum</u> <u>peltatum</u>	May apple	W,R	Sp/R
Papaveraceae			
<u>Sanguinaria</u> <u>canadensis</u>	Bloodroot	W,R	Sp/R
Fumariaceae			
<u>Corydalis</u> <u>flavula</u>	Golden corydalis	W,R	Sp/R

APPENDIX B (continued)

PLANT SPECIES OBSERVED ON THE FMPC[a]

SCIENTIFIC NAME	COMMON NAME	HABITAT[b]	OCCURRENCE/[c] ABUNDANCE
Brassicaceae			
Thlaspi sp.	Pennycress	P	Sp/R*
Capsella bursa-pastoris	Shepherd's purse	IG,F,R	Sp/R*
Draba verna	Whitlow-grass	F,R	Sp/R*
Dentaria laciniata	Cut-leaved toothwort	W,R	Sp/R
Arabis laevigata	Smooth rock cress	R	Sp/R
Arabis sp.	Rock cress	R	Sp/R
Barbarea vulgaris	Winter cress	IG,F,P,W,R	Sp/C*
Allaria officinalis	Garlic mustard	P,W,R	Sp/C*
Unknown mustard		W	Su/R
Saxifragaceae			
Heuchera americana	Alum-root	W,R	Su/O
Platanaceae			
Platanus occidentalis	American sycamore	W,R	Y/C
Rosaceae			
Potentilla simplex	Common cinquefoil	W	Sp/R
Potentilla canadensis	Dwarf cinquefoil	W	Sp/R
Geum vernum	Spring avens	W	Sp/O
G. canadense	Guem	F,P,W,R	Su/O
Geum sp.	Avens	W,R	Sp/O
Rubus allegheniensis	Blackberry	F,P,W,R	Su/O
R. occidentalis	Black raspberry	P,R	Sp/R
Rubus sp.	Bramble/dewberry/ Blackberry	P,W	Sp/O
Agrimonia parviflora	Small flowered agrimony	W	Su/O
Rosa setigera	Prairie rose	F	Su/R
R. multiflora	Multiflora rose	IG,P,W,R	Sp-Su/O*
Prunus serotina	Wild cherry	W,R	Y,R
P. hortulana	Goose plum	W	Y/R
Prunus sp.	Cherry	P	Y/R
Crateagus sp.	Hawthorn	R	Y/R
Caesalpiniaceae			
Cercis canadensis	Redbud	F,R	Y/R
Gleditsia triacanthos	Honey-locust	W,R	Y/O
Gymnocladus dioica	Kentucky coffee-tree	W	Y/R
Fabaceae (Leguminosae)			
Trifolium pratense	Red clover	IG,P,W	Sp-Su/O*
T. repens	White clover	IG,P,W,R	Sp,Su/C*
Melilotus alba	White sweet clover	F	Su/R*
M. officinalis	Yellow sweet clover	P,R	Sp-Su/R*

APPENDIX B (continued)

PLANT SPECIES OBSERVED ON THE FMPC[a]

SCIENTIFIC NAME	COMMON NAME	HABITAT[b]	OCCURRENCE/[c] ABUNDANCE
Medicago lupulina	Black medick	IG,F,P,W,R	Sp-Su/O*
Robinia pseudoacacia	Black locust	R,W,R	Y/R
Apios americana	Ground-nut	P,R	Su/R
Oxalidaceae			
Oxalis europea	Wood sorrel	P	Sp/O
O. stricta	Yellow wood sorrel	IG,P,W,R	Sp,Su/C*
Oxalis sp.	Wood sorrel	P,W,R	Su,Sp/R
Rutaceae			
Dictamnus albus	Burning bush	F,R	Y/O* (cultivar)
Euphorbiaceae			
Acalypha rhomboidea	Copper leaf	IG,P,W	Su/O
Anacardiaceae			
Rhus radicans	Poison-ivy	F,P,W,R	Sp-Su/O
Celastraceae			
Celastrus scandens	Bittersweet	R	Sp/R
Aceraceae			
Acer saccharum	Sugar maple	W,R	Y/C
A. nigrum	Black maple	R	Y/R
A. rubrum	Red maple	W	Y/R
A. saccharinum	Silver maple	W,R	Y/O
A. negundo	Box elder	F,W,R	Y/C
Hippocastanaceae			
Aesculus glabra	Ohio-buckeye	W,R	Y/O
Balsaminaceae			
Impatiens sp.	Touch-me-not/jewelweed	P,W,R	Sp-Su/O
Vitaceae			
Vitis riparia	Riverbank grape	R	Sp-Su/R
Vitis sp.	Grape	F,P,W,R	Sp-Su/O
Parthenocissus quinquefolia	Virginia creeper	F,P,W,R	Sp-Su/C
Hypericaceae			
Hypericum sp.	St. Johnswort	P	Su/R
Violaceae			
Viola sp.	Violet	IG,P,W,R	Su,Sp/O

APPENDIX B (continued)

PLANT SPECIES OBSERVED ON THE FMPC[a]

SCIENTIFIC NAME	COMMON NAME	HABITAT[b]	OCCURRENCE/ ABUNDANCE[c]
Onagraceae			
Epilobium sp.	Willow-herb	R	Sp/R
Oenothera biennis	Evening primrose	R	Sp/R
Umbelliferae			
Sanicula canadensis	Black snakeroot	W	Su/O
Sanicula sp.	Black snakeroot	W,R	Su,Sp/O
Osmorhiza claytoni	Sweet cicely	P,W,R	Sp/O
Daucus carota	Wild carrot	IG,F,P,W,R	Sp-Su/O*
Chaerophllum procumbens	Wild chervil	W,R	Sp/R
Carum carvi	Caraway	W	Su/R*
Conium maculatum	Poison hemlock	IG,F,R	Sp/O*
Pastinaca sativa	Wild parsnip	P,F	Sp,Su/O*
Cornaceae			
Cornus drummondii	Roughleaf dogwood	W,R	Y/C
C. racemosa	Red-panicled dogwood	W	Y/R
Cornus sp.	Dogwood	P	Y/R
Primulaceae			
Lysimachia nummularia	Moneywort	W,R	Sp-Su/R*
Lysimachia sp.	Loosestrife	R	Sp/R
Ebenaceae			
Diospyros virginiana	Persimmon	W	Y/R
Oleaceae			
Fraxinus americana	White ash	P,W,R	Y/C
Fraxinus sp.	Ash	W	Y/R
Apocynaceae			
Apocynum sp.	Dogbane	P	Sp/O
Ascelepiadaceae			
Asclepias syriaca	Common milkweed	IG,W	Sp/R
Asclepias sp.	Milkweed	F,P,W,R	Su,Sp/O
Convolvulaceae			
Ipomea pandurata	Wild potato-vine	P	Su/O
Ipomea sp.	Morning glory	R	Su/R
Convolvulus arvensis	Field bindweed	IG,P,W	Su/O*
C. sepium	Hedge-bindweed	P,R	Su/R*
Convolvulus sp.	Bindweed	P,R	Su,Sp/C

APPENDIX B (continued)

PLANT SPECIES OBSERVED ON THE FMPC[a]

SCIENTIFIC NAME	COMMON NAME	HABITAT[b]	OCCURRENCE/[c] ABUNDANCE
Polemoniaceae			
Phlox divaricata	Blue phlox	R	Sp/R
Hydrophyllaceae			
Phacelia purshii	Miami mist	W,R	Sp/O
Boraginaceae			
Mertensia virginiana	Bluebells	R	Sp/R
Verbenaceae			
Verbena urticifolia	White verain	P,W,R	Su/O
Labiatae			
Glechoma hederacea	Ground-ivy	IG,P,R,W	Su,Sp/O*
Prunella vulgaris	Heal-all	P	Su/R*
Lamium amplexicaule	Henbit	R	Sp/R*
L. purpureum	Purple dead-nettle	IG,P,F,W,R	Sp/O*
Leonurus cardiaca	Common motherwort	P	Su/R*
Unknown mint		P	Sp/R
Solanaceae			
Physalis heterophylla	Ground cherry	IG,P,W,R	Su/O
Solanum carolinense	Horse-nettle	IG,P,W	Su/O
Datura stramonium	Jimsonweed	F,P	Su/R
Scrophulariaceae			
Verbascum blattaria	Moth-mullein	IG	Su/R*
Veronica peregrina	Purslane speedwell	IG	Sp/R
Veronica sp.	Speedwell	P,R	Sp/R
Bignoniceae			
Campsis radicans	Trumpet creeper	F,P	Su,Sp/O
Plantaginaceae			
Plantago major	Common plantain	IG,W	Sp,Su/R*
P. lanceolata	English plantain	IG,P,W	Su,Sp/O*
Plantago sp.	Plantain	IG,P	Su/R
Rubiaceae			
Galium aparine	Cleavers	F,P,W,R	Sp,Su/C
Galium sp.	Bedstraw	W,R	Sp/R
Caprifoliaceae			
Sambucus canadensis	Common elder-berry	P,W	Su,Sp/R
Lonicera japonica	Japanese honeysuckle	F,W,R	Sp-Su/O*
Lonicera sp.	Honeysuckle	F,P,W,R	Su,Sp/O

APPENDIX B (continued)

PLANT SPECIES OBSERVED ON THE FMPC[a]

SCIENTIFIC NAME	COMMON NAME	HABITAT[b]	OCCURRENCE/[c] ABUNDANCE
Valerianaceae			
Valerianella radiata	Corn salad	W	Sp/R
Valerianella sp.	Corn salad	F,W,R	Sp/R
Dipsacaceae			
Dipsacus sylvestris	Teasel	F,P	Su/R*
Campanulaceae			
Campanula americana	Tall bellflower	R	Su/R
Compositae			
Helianthus tuberosus	Sunflower	R	Su/O
Actinimeris alternifolia	(Verbesina) Crown-beard	R	Su/O
Bidens vulgata	Beggar-ticks	P,R	Su,Sp/O
Polymnia sp.	Leafcup	R	Su/R
Silphium trifoliolatum	Rosinweed	R	Su/O
Ambrosia trifida	Great ragweed	F,P,R	Su/O
A. artemisiifolia	Common ragweed	IG,F,P,W,R	Su/C
Ambrosia sp.	Ragweed	F,P	Su-Su/R
Xanthium strumarium var. canadensis	Cocklebur	R	Su/R
X. echinatum	Cocklebur	R	Sp/R
Achillea millefolium	Yarrow	IG,P,F,W	Sp-Su/O
Senecio sp.	Ragwort	W,R	Sp-Su/R
Solidago sp.	Goldenrod	IG,F,P,W,R	Su,Sp/C
Aster sp.	Aster	IG,F,P,W,R	Su,Sp/C
Erigeron annuus	Daisy fleabane	W	Su/R
Erigeron sp.	Fleabane	IG	Sp/R
Eupatorium rugosum	White snakeroot	F,R	Sp/R
Eupatorium sp.	Thoroughwort	P,W,R	Su,Sp/R
Vernonia altissima	Tall ironweed	IG,F,P,W,R	Sp-Su/C
V. gigantea	Ironweed	IG,P,R	Sp/R
Arctium sp.	Burdock	R	Su/R
Cirsium altissimum	Tall thistle	P	Su/O
C. arvense	Canada thistle	IG	Su/R*
Cirsium sp.	Thistle	IG,F,P,W	Su,Sp/C
Taraxacum officinale	Common dandelion	IG,F,P,W,R	Su-Sp/C*
Lactuca biennis	Blue lettuce	W	Su/R
Cichorium intybus	Chicory	IG	Su/R*
Unknown Compositae		R	Sp/R

APPENDIX B (continued)
PLANT SPECIES OBSERVED ON THE FMPC[a]

[a] Adapted from Facemire et al. (1990).

Sightings identified to genus only do not necessarily indicate one species.

[b] IG = Introduced Grassland	R = Rare, very seldom seen or collected
F = Reclaimed Fly Ash Pile	O = Occasional, seen or collected a few times
P = Planted Pine	C = Common, seen regularly
W = Woodlands/Woodlots	A = Abundant, very numerous
R = Riparian	Terminology is that of Facemire et al. (1990)

[c] * = planted ornamental species or cultivar/non-native introduced or escape species

F = Fall
Sp = Spring
W = Winter
Su = Summer
Y = Yearlong

[d] When separated by a hyphen, this indicates a relatively constant frequency for both seasons.

[e] When separated by a comma, first season indicates season of highest frequency although it may persist throughout more than one.

Nomenclature from Gleason and Cronquist (1963).

APPENDIX C (continued)

MAMMALS OBSERVED ON THE FMPC[a]

[a] Adapted from Facemire et al. (1990) and RI/FS threatened and endangered species surveys.

[b] IG = Introduced Grassland
F = Reclaimed Fly Ash Pile
P = Pine Plantations
W = Deciduous Woodlands
R = Riparian
U = Unknown

[c] R = Rare
O = Occasional
C = Common
A = Abundant
I = Incidental sighting, abundance unknown

[d] The Indiana bat (Myotis sodalis), a Federally-listed endangered species, was observed on the Great Miami River near Ross, Ohio, and habitat along Paddy's Run on the FMPC is rated from fair to excellent for this species. See Chapter 4.0.

[e] The report by Facemire et al. (1990) does not list Peromyscus leucopus in its Catalogue of Species, but does list P. maniculatus, the deer mouse. However, the text of Facemire et al. (1990) states that P. maniculatus was absent from the FMPC, while numbers of P. leucopus were present. This RI/FS report assumes that the Catalogue of Species, not the text, of Facemire et al. (1990) is in error.

APPENDIX D (continued)

BIRDS OBSERVED ON THE FMPC[a]

SCIENTIFIC NAME	COMMON NAME	HABITAT[b]	OCCURRENCE/[c] ABUNDANCE
Hylocichla mustelina	Wood thrush	W, R	Su/C
Turdus migratorius	American robin	IG, F, P, W, R	W, Su/A
Dumetella carolinesis	Gray catbird	P, W, R	Su/C
Mimus polyglottos	Northern mockingbird	IG	W, Su/U
Toxostoma rufum	Brown thrasher	F, P, W, R	Su/C
Bombycilla cedrorum	Cedar waxwing	F, P, W, R	Su/C
Sturnus vulgaris	European starling	IG, F, P, R	W, Su/A
Vireo griseus	White-eyed vireo	W	Su/U
Vireo gilvus	Warbling vireo	W, R	Su/O
Vireo philadelphicus	Philadelphia vireo	W	Su/R
Vireo olivaceus	Red-eyed vireo	W, R	Su/R
Vireo solitarius	Solitary vireo	W	Sp/R
Vermivora peregrina	Tennessee warbler	F, R, W	Sp/R
Dendroica petechia	Yellow warbler	P, W, R	Su/O
Mniotilta varia	Black-and-white warbler	W	Su/R
Oporonis philadelphia	Mourning warbler	R	Sp/R
Vermivora pinus	Blue-winged warbler	W	Sp/R
Dendroica coronata	Yellow-rumped warbler	P, W, R	Sp/R
Dendroica virens	Black-throated green warbler	W, R	Sp/R
Dendroica striata	Blackpoll warbler	W	Sp/R
Seiurus noveboracensis	Northern waterthrush	R	Sp/R
Seiurus motacilla	Louisiana waterthrush	R	Su/R
Setophaga ruticilla	American redstart	W	Sp/R
Geothlypis trichas	Common yellowthroat	IG, F, P, W, R	Su/A
Icteria virens	Yellow-breasted chat	W	Su/R
Piranga rubra	Summer tanager	W, R	Su/R
Piranga olivacea	Scarlet tanager	W, R	Su/O
Cardinalis cardinalis	Northern cardinal	IG, F, P, W, R	W, Su/A
Pheucticus ludovicianus	Rose-breasted grosbeak	W, R	Sp/R
Passerina cyanea	Indigo bunting	IG, F, P, W, R	Sp/C
Pipilo eyrthropthalmus	Rufous-sided towhee	F, P, W, R	W, Su/C
Spizella arborea	American tree sparrow	IG, P, W	W/O
Melospiza georgiana	Swamp sparrow	W	Sp/R
Spizella passerina	Chipping sparrow	P, W	Su/O
Spizella pusilla	Field sparrow	IG, F, P, W, R	Su/A
Passerculus sandwichensis	Savannah sparrow	IG	Su/O
Ammodramus savannarum	Grasshopper sparrow	IG, F	Su/O
Melospiza melodia	Song sparrow	IG, F, P, W, R	W, Su/A
Zonotrichia albicollis	White-throated sparrow	W	W/R
Junco hyemalis	Dark-eyed junco	IG, P, W, R	W/C
Agelaius phoeniceus	Red-winged blackbird	IG, F, P, W, R	W, Su/A
Sturnella magna	Eastern meadowlark	IG, F, P, R	W, Su/C
Quiscalus quiscula	Common grackle	IG, F, P, W, R	Su/C
Molothrus ater	Brown-headed cowbird	F, P, W, R	Su/C
Icterus galbula	Northern oriole	F, W, R	Su/C

APPENDIX D (continued)

BIRDS OBSERVED ON THE FMPC[a]

SCIENTIFIC NAME	COMMON NAME	HABITAT[b]	OCCURRENCE/[c] ABUNDANCE
Molothrus ater	Brown-headed cowbird	F, P, W, R	Su/C
Icterus galbula	Northern oriole	F, W, R	Su/C
Carduelis tristis	American goldfinch	IG, F, P, W, R	W, Su/A
Passer domesticus	House sparrow	IG, R	W, Su/O
Carpodacus mexicanus	House finch	P, R	Sp, Su/R

a - Adapted from Facemire et al. (1990).

b - IG = Introduced Grassland
F = Reclaimed Fly Ash Pile
P = Pine Plantations
W = Woodlands/Woodlots
R = Riparian

c - F = Fall; Sp = Spring; W = Winter; Su = Summer; Y = Yearlong
R = Rare, very seldom seen or collected
O = Occasional, seen or collected a few times
C = Common, seen regularly
A = Abundant, very numerous

Terminology is that of Facemire et al. (1990)

APPENDIX E

AMPHIBIANS AND REPTILES OBSERVED ON THE FMPC[a]

SCIENTIFIC NAME	COMMON NAME	HABITAT[b]
BUFONIDAE	Bufonids and Toads	
Bufo americanus	American toad	IG, P
Bufo woodhousei fowleri	Fowler's toad	IG, P
RANIDAE	Ranids	
Rana catesbiana	Bull frog	R
Rana clamitans	Green frog	R
HYLIDAE	Hylids and Treefrogs	
Hyla crucifer	Spring peeper	R
Acris crepitans	Northern cricket frog	R
COLUBRIDA	Colubrids	
Regina septemvittata	Queen snake	R
Nerodia sipedon	Northern watersnake	R
Thamnophis butleri	Butler's garter snake	P
Elaphe obsoleta	Black rat snake	W
EMYDIDAE	Emydid Turtles	
Terrapene carolina	Box turtle	P, R
CHELYDRIDAE	Chelydrid Turtles	
Chelydra serpentina	Common snapping turtle	R
TRIONYCHIDAE	Trionychid Turtles	
Trionyx muticus	Smooth softshell turtle	R

a Source: Facemire et al. (1990). Presence only was recorded.

b IG = Introduced Grassland
P = Planted Pine
W = Deciduous Woodlands
R = Riparian

APPENDIX F

INSECTS, SPIDERS, MITES, TICKS, AND MOLLUSCS COLLECTED AT THE FMPC[a]

SCIENTIFIC NAME	COMMON NAME	HABITAT[b]	RELATIVE[c] ABUNDANCE
COLLEMBOLA	Springtails		
Entomobryidae	Elongate springtails	IG, P, W	A
Poduridae	Elongate springtails	P	R
Sminthuridae	Globular springtails	IG, F, P, W	
ODONATA	Dragonflies and Damselflies		
Coenagrionidae	Narrow-winged damselflies	R	R
Libellulidae	Common skimmers	F, R	R
ORTHOPTERA	Grasshoppers, Katydids, Crickets, Cockroaches, Mantids, and Walkingsticks		
Acrididae	Short-horned grasshoppers	IG, F, P, W, R	A
Gryllidae	Crickets	IG, F, P, W, R	C
Mantidae	Mantids	F, W, R	O
Phasmidae	Walking sticks	F, R	O
Tetrigidae	Pygmy grasshoppers	R	R
Tettigoniidae	Long-horned grasshoppers and Katydids	IG, F, P, W, R	C
PSOCOPTERA	Psocids	F, W, R	C
THYSANOPTERA	Thrips	IG, F, P, W, R	C
HEMIPTERA	Bugs		
Anthocoridae	Flower bugs; Minute pirate bugs	IG, P, R	O
Aradidae	Flat Bugs; Fungus bugs	F	O
Berytidae	Stilt bugs	IG, F, P, W	O
Coreidae	Leaf-footed bugs	R	R
Corimelaenidae	Negro bugs	IG, P,R	O
Lygaeidae	Chinch bugs; Milkweed bugs, etc.	IG, P, W, R	O
Miridae	Leaf bugs; Plant bugs	IG, F, P, W, R	C
Nabidae	Damsel bugs	IG, P, W, R	O
Pentatomidae	Stink bugs	IG, F, P, W, R	O
Phymatidae	Ambush bugs	IG, R	R
Reduviidae	Assassin bugs	IG, F, P, W, R	C
Rhopalidae	Unknown	IG,	R
Saldidae	Shore bugs	R	R
Scutelleridae	Shield bugs; Shield-backed bugs	W	R
Tingididae	Lace bugs	F, W, R	C

APPENDIX F (continued)

INSECTS, SPIDERS, MITES, TICKS, AND MOLLUSCS
COLLECTED AT THE FMPC[a]

SCIENTIFIC NAME	COMMON NAME	HABITAT[b]	RELATIVE[c] ABUNDANCE
HOMOPTERA	Cicadas, Hoppers, Whiteflies, Aphids, and Scale Insects		
Acanaloniidae	Acanaloniid planthoppers	F, P, W, R	C
Actiopheridae	Unknown	P	R
Aleyrodidae	Whiteflies	R	O
Aphididae	Aphids; Plant lice	IG, F, P, W, R	C
Cercopidae	Froghoppers; Spittlebugs	IG, F, P, W, R	C
Cicadellidae	Leafhoppers	IG, F, P, W, R	A
Cicadidae	Cicadas	R	R
Cixiidae	Cixiid planthoppers	R	O
Coccidae	Scales	P	R
Delphacidae	Delphacid planthoppers	IG, P, R	O
Dictyopharidae	Dictyopharid planthoppers	IG, P, W	O
Flatidae	Flatid planthoppers	F, W, R	C
Fulgoridae	Fulgorid planthoppers	IG	R
Issidae	Issid planthoppers	R	R
Membracidae	Treehoppers	IG, F, P, W, R	O
Psylliidae	Jumping plant lice	R	O
NEUROPTERA	Nerve-winged Insects		
Chrysopidae	Green lacewings, Common lacewings	F	O
Hemerobiidae	Brown lacewings	R	R
COLEOPTERA	Beetles		
Anthribidae	Fungus weevils	P, R	R
Cerambycidae	Long-horned Wood-boring beetles	IG, W	R
Chrysomelidae	Leaf beetles	IG, F, P, W, R	A
Cicindelidae	Tiger beetles	F, R	O
Coccinellidae	Ladybugs	IG, P, R	O
Cucujidae	Flat bark beetles	P	R
Curculionidae	Snout beetles	IG, F, P, W, R	C
Elateridae	Click beetles	F	R
Histeridae	Hister beetles	R	R
Lampyridae	Lightning bugs	IG, P, R	O
Lycidae	Net-winged beetles	W	R
Meloidae	Blister beetles; Oil beetles	IG, P	O
Mordellidae	Tumbling flower beetles	IG, F, P, W, R	O
Nitidulidae	Sap beetles	IG, W, R	O
Scarabaeidae	Scarab beetles	IG, F, P, W, R	O
Staphylinidae	Rove beetles	IG, P, W	O

APPENDIX F (continued)

INSECTS, SPIDERS, MITES, TICKS, AND MOLLUSCS
COLLECTED AT THE FMPC[a]

SCIENTIFIC NAME	COMMON NAME	HABITAT[b]	RELATIVE[c] ABUNDANCE
MECOPTERA	Scorpionflies		
Panorpidae	Common scorpionflies	W,R	O
LEPIDOPTERA	Butterflies and moths		
Ctenuchidae	Unknown	F	R
Danaidae	Milkweed butterflies	F, W, R	R
Lycaenidae	Gossamer-winged butterflies	F	R
Noctuidae	Noctuid moths	F, P	R
Nymphalidae	Brush-footed butterflies	F, W, R	O
Pieridae	White, Sulfur and Orange-tip butterflies	IG	R
DIPTERA	Flies		
Agromyzidae	Leaf-miner flies	IG, W, R	O
Anthomyzidae	Anthomyzid flies	IG, P	R
Asilidae	Robber flies	IG, F, P, W, R	O
Calliphoridae	Blow flies	IG, F, P, W, R	O
Cecidomyiidae	Gall gnats	IG, P, W, R	O
Chamaemyiidae	Aphid flies	P	O
Chironomidae	Midges	R	O
Chloropidae	Fruit flies	IG, F, P, W, R	A
Culicidae	Mosquitoes	IG, P, W, R	O
Curtonotidae	Curtonotid flies	IG	R
Dolichopodidae	Long-legged flies	IG, P, W, R	C
Drosophilidae	Small fruit flies	IG, P, W, R	C
Empididae	Dance flies	P, R	R
Ephydridae	Shore flies	R	O
Heleomyzidae	Heleomyzid flies	IG, P	R
Lauxaniidae	Lauxaniid flies	W, R	O
Lonchopteridae	Spear-winged flies	IG	R
Micropezidae	Stilt-legged flies	IG	R
Muscidae	Muscid flies	IG, F, P, W, R	C
Mycetophilidae	Fungus gnats	IG, W, R	O
Otitidae	Picture-winged flies	R	R
Phoridae	Humpbacked flies	IG, W, R	O
Piophilidae	Skipper flies	W, R	O
Pipunculidae	Big-headed flies	IG, F, P, W, R	O
Platystomatidae	Picture-winged flies	IG, W	O
Psychodidae	Moth flies	R	R
Rhagionidae	Snipe flies	IG, R	R
Sarcophagidae	Flesh flies	IG, F, P, R	O
Sciaridae	Dark-winged fungus gnats	IG, P, W, R	C

APPENDIX F (continued)

INSECTS, SPIDERS, MITES, TICKS, AND MOLLUSCS COLLECTED AT THE FMPC[a]

SCIENTIFIC NAME	COMMON NAME	HABITAT[b]	RELATIVE[c] ABUNDANCE
Sciomyzidae	Marsh flies	IG, F, P, R	O
Sepsidae	Black scavenger flies	IG, P, W, R	O
Stratiomyidae	Soldier flies	IG	R
Syrphidae	Syrphid flies	IG, F, P, W, R	C
Tabanidae	Horse flies, Deer flies, Greenheads	IG, P, W	O
Tachinidae	Tachinid flies	IG, P, W	O
Tephritidae	Fruit flies	IG, F, P, W, R	C
Therevidae	Stiletto flies	IG, P	O
Tipulidae	Crane flies	W, R	O
HYMENOPTERA	Ants, Wasps, Bees, Chalcids, Ichneumons, Sawflies		
Apidae	Bumblebees; Honey bees	IG, F, W, R	O
Bethylidae	Bethylids	IG, R	R
Braconidae	Braconids	IG, F, P, W, R	C
Cephidae	Stem sawflies	P	R
Chalcidoidea	Chalcids	IG, F, P, W, R	C
Colletidae	Plasterer and Yellow-faced bees	IG, P	R
Cynipidae	Gall wasps	IG, P, W, R	O
Diapriidae	Diapriids	P, R	O
Diprionidae	Conifer sawflies	P	R
Formicidae	Ants	IG, F, P, W, R	C
Halictidae	Mining bees	IG, F, P, W, R	C
Ichneumonidae	Ichneumons	IG, P, W, R	O
Megachilidae	Leafcutting bees	R	R
Platygasteridae	Platygasterids	IG, F, P, W, R	O
Pompilidae	Spider wasps	R	R
Proctotrupidae	Parasitic wasps	P, W	R
Scelionidae	Scelionids	IG, W, R	O
Siricidae	Horntails	W	R
Sphecidae	Sphecid wasps	IG, F, P, W, R	O
Tenthredinidae	Sawflies	P	R
Vespidae	Paper wasps	IG, F, P, W, R	C
COLEOPTERA LARVAE	Beetles	IG, P	C
LEPIDOPTERA LARVAE	Butterflies and Moths	IG, P	O
TRICHOPTERA LARVAE	Caddisflies	R	R

APPENDIX F (continued)

INSECTS, SPIDERS, MITES, TICKS, AND MOLLUSCS
COLLECTED AT THE FMPC[a]

SCIENTIFIC NAME	COMMON NAME	HABITAT[b]	RELATIVE[c] ABUNDANCE
NON-INSECT SPIDERS, MITES, TICKS, AND MOLLUSCS			
Acarina	Mites and Ticks	IG, F, P, W, R	C
Araneida	Spiders	IG, F, P, W, R	A
Phalangida	Harvestmen	P, W	R
Gastropoda	Snails	W, R	C

[a] - Adapted from Facemire et al. (1990).

[b] - IG = Introduced Grassland
F = Reclaimed Fly Ash Pile
P = Pine Plantations
W = Deciduous Woodlands
R = Riparian Woodlands

[c] - R = Rare, very seldom seen or collected
O = Occasional, seen or collected a few times
C = Common, seen regularly
A = Abundant, very numerous

Terminology is that of Facemire et al. (1990)

APPENDIX G

FISH OBSERVED ON THE FMPC[a]

SCIENTIFIC NAME	COMMON NAME	PROPORTION OF CATCH (%)[b]	RELATIVE ABUNDANCE[c]
CYPRINIDAE	Minnows, Shiners, Daces, Chubs		
Campostoma anomalum	Stoneroller minnow	18	A
Carpus carpio	Carp	< 1	R
Ericymba buccata	Silverjaw minnow	3	O
Notropis ardens	Rosefin shiner	6	C
Notropis atherinoides	Emerald shiner	< 1	R
Notropis chrysocephalus	Striped shiner	1	O
Notropis spilopterus	Spotfin shiner	7	C
Notropis stramineus	Sand shiner	< 1	R
Notropis whipplei	Steelcolor shiner	< 1	R
Phenacobius mirabilis	Suckermouth minnow	< 1	R
Phoxinus erythrogaster	Redbelly dace	< 1	R
Pimephales notatus	Bluntnose minnow	27	A
Rhinichthys atratulus	Blacknose dace	2	O
Semotilus atromaculatus	Creek chub	13	C
CATASTOMIDAE	Suckers		
Catastomus commersoni	White sucker	1	O
CENTRARCHIDAE	Sunfish, bass		
Lepomis humilus	Orange-spotted sunfish	< 1	R
Lepomis macrochirus	Bluegill	< 1	R
Lepomis spp.	Sunfish hybrid	< 1	R
Micropterus salmoides	Largemouth bass	< 1	R
PERCIDAE	Darters		
Etheostona caeruleum	Rainbow darter	< 1	R
Etheostona flabellare	Fantail darter	6	C
Etheostona nigrum	Johnny darter	8	C
Etheostona spectabile	Orangethroat darter	10	C

[a] Adapted from Facemire et al. (1990).

[b] Total catch for all sampling periods equals 6668 individual fish.

[c]
R = Rare < 1%
O = Occasional 1- 5%
C = Common 5-15%
A = Abundant > 15%

APPENDIX H

FISH IDENTIFIED FROM THE LOWER MAINSTEM OF THE GREAT MIAMI RIVER AND FIVE TRIBUTARIES[a]

SCIENTIFIC NAME	COMMON NAME	PROPORTION OF CATCH (%)[b]	RELATIVE ABUNDANCE[c]
Alosa chrusochloris	Skipjack herring	2	O
Ambloplites rupestris	Rock bass	1	O
Amia calva	Bowfin	<1	R
Aplodinotus grunniens	Freshwater drum	1	O
Campostoma anomalum	Stoneroller minnow	<1	R
Carassius auratus	Goldfish	3	O
Carpiodes carpio	River carpsucker	1	O
Carpiodes cyprinus	Quillback carpsucker	<1	R
Carpiodes velifer	Highfin carpsucker	<1	R
Catastomus commersoni	White sucker	2	O
Cyprinus carpio	Common carp	22	A
Cyprinus X Carassius	Hybird	1	O
Dorosoma cepedianum	Gizzard shad	14	C
Esox americanus	Grass pickerel	<1	R
Esox lucius	Northern pike	<1	R
Etheostoma blennioides	Greenside darter	<1	R
Hiodon tergisus	Mooneye	<1	R
Hybopsis storeriana	Silver chub	<1	R
Hypentelium nigricans	Northern hog sucker	2	O
Ictalurus melas	Black bullhead	<1	R
Ictalurus natalis	Yellow bullhead	<1	R
Ictalurus nebulosus	Brown bullhead	<1	R
Ictalurus punctatus	Channel catfish	1	O
Ictiobus bubalis	Smallmouth buffalo	<1	R
Ictiobus niger	Black buffalo	<1	R
Lepisosteus osseus	Longnose gar	<1	R
Lepomis cyanellus	Green sunfish	11	C
Lepomis gibbosus	Pumpkinseed sunfish	<1	R
Lepomis gulosus	Warmouth	<1	R
Lepomis humilis	Orangespotted sunfish	<1	R
Lepomis macrochirus	Bluegill	3	O
Lepomis megalotis	Longear sunfish	8	C
Lepomis spp.	Hybird sunfish	<1	R
Micropterus dolomieui	Smallmouth bass	2	O
Micropterus salmoides	Largemouth bass	1	O
Micropterus salmoides	Spotted bass	<1	R
Minytrema melanops	Spotted sucker	1	O
Morone chrysops	White bass	<1	R
Moxostoma anisurum	Silver redhorse	<1	R
Moxostoma carinatur	River redhorse	<1	R
Moxostoma duquesnei	Black redhorse	1	O

APPENDIX H

(CONTINUED)

FISH IDENTIFIED FROM THE LOWER MAINSTEM OF THE GREAT MIAMI RIVER AND FIVE TRIBUTARIES[a]

SCIENTIFIC NAME	COMMON NAME	PROPORTION OF CATCH (%)[b]	RELATIVE ABUNDANCE[c]
Moxostoma erythrurum	Golden redhorse	5	C
Moxostoma macrolepidotum	Shorthead redhorse	<1	R
Nocomis micropogon	Riverchub	<1	R
Notemigonus chrysoleucas	Golden shiner	2	O
Notropis ardens	Rosyfin shiner	<1	R
Notropis atherinoides	Emerald shiner	1	O
Notropis chrysocephalus	Striped shiner	1	O
Notropis photogenis	Silver shiner	1	O
Notropis rubellus	Rosyface shiner	<1	R
Notropis spilopterus	Spotfin shiner	11	C
Notropis stramineus	Sand shiner	<1	R
Notropis volucellus	Mimic shiner	<1	R
Noturus flavus	Stonecat madtom	<1	R
Noturus gyrinus	Tadpole madtom	<1	R
Perca flavescens	Yellow perch	<1	R
Percina caprodes	Logperch	<1	R
Phenacobius mirabilis	Suckermouth minnow	<1	R
Pimephales notatus	Bluntnose minnow	1	O
Pimephales promelas	Fathead minnow	<1	R
Pomoxis annularis	White crappie	1	O
Pomoxis nigromaculatus	Black crappie	<1	R
Pylodictus olivaris	Flathead catfish	<1	R
Semotilus atromaculatus	Creek chub	<1	R
Stizostedion canadense	Sauger	<1	R
Stizostedion vitreum	Walleye	<1	R

[a] Adapted from OEPA (1985)

[b, c]
R = Rare < 1%
O = Occasional 1- 5%
C = Common 5-15%
A = Abundant > 15%

APPENDIX I

FISH SPECIES OBSERVED IN THE LOWER MAINSTEM OF THE GREAT MIAMI RIVER BUT NOT RECOLLECTED DURING 1980[a]

SCIENTIFIC NAME	COMMON NAME
Acipenser fluvescens	Lake sturgeon
Alosa pseudoharengus	Alewife
Ammocrypta pellucida	Eastern sand darter
Anguilla rostrata	American eel
Cycleptus elongatus	Blue sucker
*Ericymba buccata	Silverjaw minnow
Erimyzon oblongus	Creek chubsucker
Esox masquinongy	Muskellunge
*Etheostoma caeruleum	Rainbow darter
Etheostoma camurum	Bluebreast darter
*Etheostoma flabellare	Fantail darter
Etheostoma microperca	Lease darter
*Etheostoma nigrum	Johnny darter
*Etheostoma spectabile	Orangethroat darter
Etheostoma variegatum	Variegate darter
Etheostoma zonale	Banded darter
Exoglossum laurae	Tonguetied chub
Hiodon alosoides	Goldeye
Hybopsis aestivalis	Speckled chub
Hybopsis amblops	Bigeye chub
Hybopsis dissimilis	Streamline chub
Hybopsis x-punctata	Gravel chub
Ichthyomyzon bdellium	Ohio lamprey
Ictalurus catus	White catfish
Ictalurus furcatus	Blue catfish
Ictiobus cyprinellus	Bigmouth buffalo
Labidesthes sicculus	Brook silverside
Lepomis microlophus	Redear sunfish
Lota lota	Burbot
Notropis blennis	River shiner
Notropis boops	Bigeye shiner
Notropis buchanani	Ghost shiner
*Notropis whipplei	Steelcolor shiner
Noturus miurus	Brindled madtom
Noturus stigmosus	Northern madtom
Percina copelandi	Channel darter
Percina maculata	Blackside darter
Percina phoxocephala	Slenderhead darter
Percina shumardi	River darter
Percopsis omiscomaycus	Trout-perch
*Phoxinus erthrogaster	Southern-redbelly dace
Polyodon spathula	Paddlefish

APPENDIX I (continued)

FISH SPECIES OBSERVED IN THE LOWER MAINSTEM OF THE GREAT MIAMI RIVER BUT NOT RECOLLECTED DURING 1980

SCIENTIFIC NAME	COMMON NAME
*<u>Rhinichthys</u> <u>atratulus</u>	Blacknose dace
<u>Scaphirhynchus</u> <u>platorynchus</u>	Shovelnose sturgeon

[a] Adapted from OEPA (1985).

* Species captured in Paddy's Run during 1986-1987 studies by Facemire et al. (1990).

APPENDIX J

BENTHIC MACROINVERTEBRATES IDENTIFIED FROM RIFFLE AND POOL HABITAT OF PADDY'S RUN[a]

SCIENTIFIC NAME	COMMON NAME	HABITAT[b]	RELATIVE[c] ABUNDANCE
DIPTERA	Flies, Mosquitoes, Midges		
Ceratopogonidae	Biting midges	P	R
Chironomidae	Midges	P,Ri	A
Simulidae	Black flies		
Simulium sp.		Ri	C
Tipulidae	Crane flies		
Hexatoma sp.		Ri	O
Dicranota sp.		Ri	R
Tipula sp.		Ri	R
Limonia sp.		Ri	R
Unidentified Tipulid		Ri	R
Tabanidae	Horseflies		
Tabanus sp.		Ri	R
Empididae			
Hemerodromia sp.		Ri	R
Ephydridae		U	R
COLEOPTERA	Beetles		
Curculionidae	Snout beetles	U	R
Hydraenidae		U	R
Psephenidae	Riffle beetles		
Psephenus herricki		Ri	O
Melyridae		U	R
Elmidae			
Stenelmis sp.		P,Ri	O
Dubiraphia sp.		Ri	R
HYMENOPTERA	Bees, Wasps		
Scelionidae		U	R
TRICHOPTERA	Caddisflies		
Lemnephilidae		U	R
Psychomyiidae		U	C
Agraylea sp.			

APPENDIX J (continued)

BENTHIC MACROINVERTEBRATES IDENTIFIED FROM RIFFLE AND POOL HABITAT OF PADDY'S RUN[a]

SCIENTIFIC NAME	COMMON NAME	HABITAT[b]	RELATIVE[c] ABUNDANCE
Hydropsychidae			
<u>Cheumatopsyche</u> sp.	Caddisfly	Ri	A
<u>Hydropsyche</u> sp.	Caddisfly .	Ri	C
Helicopsychidae			
<u>Helicopsyche</u> sp.		Ri	I
Philopotamidae			
<u>Chimarra</u> <u>obscura</u>		Ri	R
Rhyacophilidae			
<u>Rhyacophila</u> sp.		Ri	O
Polycentropodidae		U	O
EPHEMEROPTERA	Mayflies		
Caenidae			
<u>Caenis</u> sp.	Mayfly	P,Ri	A
Ephemeridae		U	R
Siphonuridae		U	R
Heptageniidae			
<u>Stenonema</u> <u>bipunctatum</u>	Mayfly	P,Ri	C
<u>Stenacron</u> sp.		Ri	R
Baetidae			
<u>Baetis</u> sp.		P	R
<u>Psuedocleon</u> sp.		Ri	R
Oligoneuriidae			
<u>Isonychia</u> sp.			
HEMIPTERA	True Bugs		
<u>Microvelia</u> sp.		U	U
PLECOPTERA	Stoneflies		
Capniidae			
<u>Allocapnia</u> sp.	Stonefly	P,Ri	A
Leuctridae		U	R
Nemouridae	Stonefly	Ri	O

APPENDIX J (continued)

BENTHIC MACROINVERTEBRATES IDENTIFIED FROM RIFFLE AND POOL HABITAT OF PADDY'S RUN[a]

SCIENTIFIC NAME	COMMON NAME	HABITAT[b]	RELATIVE[c] ABUNDANCE
Perlodidae			
Isoperla sp.		Ri	O
Chloroperlidae			
Alloperla sp.		Ri	R
Taeniopterygidae			
Taeniopteryx sp.		Ri	R
LEPIDOPTERA	Butterflies, Moths		
Lymnaeide		U	R
AMPHIPODA	Scuds, Sideswimmers		
Talitridae			
Hyalella azteca		P,Ri	R
DECOPODA	Crayfish, Shrimp		
Astacidae	Crayfish		
Orconectes rusticus		Ri	R
O. sloanii	Cincinnati crayfish	P	C
GASTROPODA	Snails, Limpets		
Physidae	Pouch snails		
Physa sp.		P,Ri	C
Ancylidae	Limpets		
Ferrissia sp.		P,Ri	R
PELECYPODA	Clams, mussels		
Sphaerium sp.	Fingernail clams	U	U
TURBELLARIA	Flatworms		
Planariidae	Planaria		
Dugesia sp.		Ri	R
OLIGOCHAETA	Aquatic earthworms	P,Ri	C
NEMATODA	Nematodes	U	O
NEMATOMORPHA	Horsehair worms	Ri	R

APPENDIX J (continued)

BENTHIC MACROINVERTEBRATES IDENTIFIED FROM RIFFLE AND POOL HABITAT OF PADDY'S RUN[a]

SCIENTIFIC NAME	COMMON NAME	HABITAT[b]	RELATIVE[c] ABUNDANCE
ARACHNIDA			
Hydracarina		U	R
COLLEMBOLA	Springtails	Ri	R
Sminthuridae		U	R
MEGALOPTERA	Alderflies, Dobsonflies, Fishflies		
Sialidae	Alderflies		
Sialis sp.		Ri	R
ISOPODA	Aquatic Sow Bugs		
Asellidae			
Lirceus fontinalis	Isopod	P,Ri	C

a - Adapted from Facemire et al. (1990) and Pomeroy et al. (1977).

b - P = Pool
Ri= Riffle
U = Unknown

c - R = Rare, very seldom seen or collected
O = Occasional, seen or collected a few times
C = Common, seen regularly
A = Abundant, very numerous
U = Unknown
I = Incidental sighting

Terminology is that of Facemire et al. (1990)

APPENDIX K

BENTHIC MACROINVERTEBRATES COLLECTED ON ARTIFICAL SUBSTRATE SAMPLERS FROM THE GREAT MIAMI RIVER[a]

SCIENTIFIC NAME	COMMON NAME	RELATIVE[b] ABUNDANCE
PORIFERA	Sponges	
Spongilla fragilaris		P
TURBELLARIA	Flatworms	
Unidentified		P
BRYOZOA	Moss animalcules	
Plumatella repens		R
Urnatella gracilis		R
ANNELIDA	Aquatic Earthworms, Leeches, Polychaetes	
Oligochaeta	Aquatic earthworms	
Helobdella sp.		P
Dina sp.		P
ISOPODA	Aquatic Sow Bugs	
Lirceus sp.	Isopod	P
EPHEMEROPTERA	Mayflies	
Stenacron sp.		O
Stenonema pulchellum (A)		C
Stenonema pulchellum (B)		C
Stenonema pulchellum (C)		A
Stenonema femoratum		P
Heptagenia sp.		P
Baetis sp.		O
Tricorythodes sp.		O
Isonychia sp.		O
ODONATA	Dragonflies, Damselflies	
Argia sp.		R
Agrion sp.		P

APPENDIX K (continued)

BENTHIC MACROINVERTEBRATES COLLECTED ON
ARTIFICAL SUBSTRATE SAMPLERS
FROM THE GREAT MIAMI RIVER[a]

SCIENTIFIC NAME	COMMON NAME	RELATIVE ABUNDANCE[b]
TRICHOPTERA	Caddisflies	
Cheumatopsyche sp.		O
Potamyia sp.		C
Symphitopsyche bifida		P
Hydropsyche orris		A
Hydropsyche bidens		O
Hydropsyche valanis		O
Hydropsyche venularis		P
Hydropsyche simulans		A
Ceraclea sp.		P
Chimarra obscura		P
COLEOPTERA	Beetles	
Stenelmis sp.		R
Dubiraphia sp.		R
Psephenus herricki	Riffle beetle	P
Dytiscus sp.	Predaceous diving beetles	P
DIPTERA	Flies, Mosquitoes, Midges	
Tipula sp.		P
Pentaneura sp.		C
Tendipedinae	Midges	P
Polypedilum illinoense		C
Polypedilum fallax		O
Polypedilum scalaenum		O
Glyptotendipes sp.		P
Cryptochironomus sp. (A)		P
Cryptochironomus sp. (B)		O
Xenochironomus sp.		P
Calopsectra rheotanytarsus		C
Corynoneura sp.		R
Ceratopogonidae	Biting Midges	P
Empididae		O

APPENDIX K (continued)

BENTHIC MACROINVERTEBRATES COLLECTED ON
ARTIFICAL SUBSTRATE SAMPLERS
FROM THE GREAT MIAMI RIVER[a]

SCIENTIFIC NAME	COMMON NAME	RELATIVE ABUNDANCE[b]
GASTROPODA	Snails, Limpets	
Ferrissia sp.	Limpets	R
Goniobasis livescens	River snail	P
PELECYPODA	Clams, Mussels	
Sphaerium sp.	Fingernail clams	P

[a] Adapted from OEPA (1985) for River Segments 10-11; data collected in 1980.

[b] P = Present — Collected in dredge (qualitative) sample only.
R = Rare — < 10 individuals on any one artificial substrate sampler.
O = Occasional — 10-50 individuals on any one artificial substrate sampler.
C = Common — 50-500 individuals on any one artificial substrate sampler.
A = Abundant — > 500 individuals on at least one artificial substrate sampler.

Artificial substrate samplers were placed at River Miles 24.8, 22.5, 15.1, 9.5, and 8.2 from July 7, 1980 to September 3, 1980. River Mile 24.8 is just upstream of the FMPC effluent line.

APPENDIX L

TOTAL URANIUM IN SOIL AND FERTILIZER AT VARIOUS DISTANCES FROM THE FMPC[a]

Sample Location[b]	Distance (km.)	Total Uranium (pCi/g) Soil	Total Uranium (pCi/g) Fertilizer
2	1.6	2.4	121
10	1.7	3.0	20
3	1.9	5.7	--
5	1.9	--[c]	0.03
7	1.9	2.7	24
8	2.0	2.7	--
6	2.7	--	--
1	3.6	4.6	3.5
13	3.9	2.2	--
9	6.2	2.4	8.9
12	33.8	--	--
11	43.5	2.1	2.0
4	62.8	2.4	--

[a] Source: WMCO (1987b)
[b] See map in WMCO (1987b)
[c] -- No sample

APPENDIX M

ISOTOPIC URANIUM CONCENTRATIONS IN SOIL AND VEGETATION ON THE FMPC[a]

Site[b]	Uranium-234 (pCi/g) Soil	Grass Leaves	Grass Roots	Forb Leaves	Forb Roots	Other
1	2.3	<0.6	<0.6	--[c]	--	--
2	2.2	--	--	<0.6	0.8	--
3	6.2	<0.6[d]	<0.6[d]	--	--	--
4	3.6	1.8	2.1	2.5	1.9	--
	--	3.2	2.2	--	--	--
5	11.0	4.0	10.7	2.5	2.7	--
6	16.5	2.4	3.4	<0.6	3.4	--
7	--	1.6	3.6	1.1	2.2	--
	--	--	1.3	--	--	--
8	2.6	<0.6	0.6	0.6	<0.6	--
9	2.9	<0.6	3.9	--	--	--
	2.6	--	--	--	--	--
10	--	2.0	12.9	3.0	0.8	--
	--	<0.6[d]	1.6[d]	--	--	--
11	1.7	--	--	<0.6	0.6	--
12	17.0	<0.6	12.8	1.1	13.7	--
13	1.3	--	--	<0.6	<0.6	1.0[e]
	--	--	--	--	--	<0.6[f]
	--	--	--	--	--	4.8[g]
14	--	--	--	3.1	10.4	<0.6[g]
15	--	<0.6	13.5	2.0	14.1	--
	--	<0.6[d]	9.7[d]	--	--	--
16	4.3	<0.6	1.2	0.9	2.3	--
17	16.0	<0.6	2.8	--	--	<0.6[h]
	--	--	--	--	--	<0.6[i]
18	14.5	0.8	8.4	0.8	2.0	--
19	14.7	1.7	3.8	--	--	--
	--	1.6	4.4	--	--	--
20	5.9	1.3	2.2	--	--	--
21	6.0	2.3	<0.6	--	--	--
22	5.1	--	--	<0.6	0.8	--
23	2.6	<0.6	<0.6	--	--	--
24	4.4	1.0	1.6	--	--	--
25	3.2	0.6	2.9	--	--	--
26	3.7	<0.6	<0.6	--	--	--
27	1.0	<0.6	<0.6	--	--	--
28	14.5	1.2[d]	2.1[d]	1.0	16.1	--
	--	--	--	1.1	4.4	--
29	3.0	<0.6	<0.6	--	--	--
30	3.4	<0.6	<0.6	--	--	--
31	2.8	<0.6	<0.6	<0.6	<0.6	--

APPENDIX M
(Continued)

ISOTOPIC URANIUM CONCENTRATIONS
IN SOIL AND VEGETATION ON THE FMPC[a]

Site[b]	Uranium-235,-236 (pCi/g) Soil	Grass Leaves	Grass Roots	Forb Leaves	Forb Roots	Other
1	<0.6	<0.6	<0.6	--	--	--
2	<0.6	--	--	<0.6	<0.6	--
3	<0.6	<0.6[d]	<0.6[d]	--	--	--
4	1.6	<0.6	<0.6	<0.6	<0.6	--
	--	<0.6	<0.6	--	--	--
5	<0.6	<0.6	<0.6	<0.6	<0.6	--
6	1.7	<0.6	<0.6	<0.6	0.9	--
7	--	<0.6	<0.6	<0.6	0.8	--
	--	--	<0.6	--	--	--
8	<0.6	<0.6	<0.6	<0.6	<0.6	--
9	<0.6	<0.6	<0.6	--	--	--
	<0.6	--	--	--	--	--
10	--	<0.6	<0.6	<0.6	<0.6	--
	--	<0.6[d]	<0.6[d]	--	--	--
11	<0.6	--	--	<0.6	<0.6	--
12	1.3	<0.6	1.2	<0.6	0.9	--
13	<0.6	--	--	<0.6	<0.6	<0.6[e]
	--	--	--	--	--	<0.6[f]
	--	--	--	--	--	0.8[g]
14	--	--	--	<0.6	1.2	<0.6[g]
15	--	<0.6	1.2	<0.6	0.9	--
	--	<0.6[d]	0.6[d]	--	--	--
16	<0.6	<0.6	<0.6	--	--	--
17	1.2	<0.6	<0.6	--	--	<0.6[h]
	--	--	--	--	--	<0.6[i]
18	1.4	<0.6	<0.6	<0.6	<0.6	--
19	0.9	<0.6	<0.6	--	--	--
	--	<0.6	<0.6	--	--	--
20	0.8	<0.6	<0.6	--	--	--
21	<0.6	<0.6	<0.6	--	--	--
22	<0.6	--	--	<0.6	<0.6	--
23	<0.6	<0.6	<0.6	--	--	--
24	<0.6	<0.6	<0.6	--	--	--
25	<0.6	<0.6	<0.6	--	--	--
26	<0.6	<0.6	<0.6	--	--	--
27	<0.6	<0.6	<0.6	--	--	--
28	1.8	<0.6[d]	<0.6[d]	<0.6	1.6	--
	--	--	--	<0.6	<0.6	--
29	<0.6	<0.6	<0.6	--	--	--
30	<0.6	<0.6	<0.6	--	--	--
31	<0.6	<0.6	<0.6	<0.6	<0.6	--

APPENDIX M
(Continued)

ISOTOPIC URANIUM CONCENTRATIONS IN SOIL AND VEGETATION ON THE FMPC[a]

	Uranium-238 (pCi/g)					
Site[b]	Soil	Grass Leaves	Grass Roots	Forb Leaves	Forb Roots	Other
1	1.9	<0.6	<0.6	--	--	--
2	2.3	--	--	<0.6	0.9	--
3	7.8	<0.6[d]	<0.6[d]	--	--	--
4	4.7	<0.6	1.6	2.4	1.0	--
	--	0.9	2.0	--	--	--
5	10.9	1.7	6.6	1.4	1.4	--
6	17.4	1.2	3.4	<0.6	5.0	--
7	--	0.9	2.6	1.0	2.9	--
	--	--	1.5	--	--	--
8	3.6	<0.6	0.7	<0.6	<0.6	--
9	5.2	<0.6	4.8	--	--	--
	4.2	--	--	--	--	--
10	--	13.7	13.7	1.1	0.7	--
	--	<0.6[d]	1.6[d]	--	--	--
11	2.6	--	--	<0.6	2.1	--
12	17.3	0.7	13.6	1.7	14.3	--
13	1.7	--	--	<0.6	<0.6	0.7[e]
	--	--	--	--	--	<0.6[f]
	--	--	--	--	--	6.3[g]
14	--	--	--	3.3	12.0	<0.6[g]
15	--	<0.6	17.2	4.2	17.4	--
	--	<0.6[d]	9.8[d]	--	--	--
16	3.3	<0.6	1.6	0.7	1.7	--
17	15.2	<0.6	2.8	--	--	<0.6[h]
	--	--	--	--	--	<0.6[i]
18	14.3	<0.6	9.5	<0.6	1.9	--
19	11.7	2.1	3.9	--	--	--
	--	1.8	4.5	--	--	--
20	6.6	1.6	2.1	--	--	--
21	5.4	3.2	<0.6	--	--	--
22	4.9	--	--	<0.6	1.5	--
23	2.7	<0.6	<0.6	--	--	--
24	4.7	0.9	1.5	--	--	--
25	2.7	<0.6	2.8	--	--	--
26	3.2	<0.6	<0.6	--	--	--
27	1.7	<0.6	<0.6	--	--	--
28	16.2	1.4[d]	2.5[d]	1.2	17.8	--
	--	--	--	1.6	5.7	--
29	3.1	<0.6	<0.6	--	--	--
30	3.1	<0.6	<0.6	--	--	--
31	2.9	<0.6	<0.6	<0.6	<0.6	--

APPENDIX M
(Continued)

ISOTOPIC URANIUM CONCENTRATIONS
IN SOIL AND VEGETATION ON THE FMPC[a]

	Total Uranium (pCi/g)					
Site[b]	Soil	Grass Leaves	Grass Roots	Forb Leaves	Forb Roots	Other
1	4.2	<d.l.[j]	<d.l.	--	--	--
2	4.5	--	--	<d.l.	1.7	--
3	14.0	<d.l.[d]	<d.l.[d]	--	--	--
4	9.9	1.8	3.7	4.9	2.9	--
	--	4.1	4.2	--	--	--
5	21.9	5.7	17.3	3.9	4.1	--
6	35.6	3.6	6.8	<d.l.	9.3	--
7	--	2.5	6.2	2.1	5.9	--
8	6.2	<d.l.	1.3	0.6	<d.l.	--
9	8.1	<d.l.	8.7	--	--	--
	6.8	--	--	--	--	--
10	--	15.7	26.6	4.1	1.5	--
	--	<d.l.[d]	3.2[d]	--	--	--
11	4.3	--	--	<d.l.	2.7	--
12	35.6	0.7	27.6	2.8	28.9	--
13	3.0	--	--	<d.l.	<d.l.	1.7[e]
	--	--	--	--	--	<d.l.[f]
	--	--	--	--	--	11.9[g]
14	--	--	--	6.4	23.6	<d.l.[h]
15	--	<d.l.	31.9	6.2	32.4	--
	--	<d.l.[d]	20.1[d]	--	--	--
16	7.6	<d.l.	2.8	1.6	4.0	--
17	32.4	<d.l.	5.6	--	--	0.6[h]
	--	--	--	--	--	<d.l.[i]
18	30.2	0.8	17.9	0.8	3.9	--
19	27.3	3.8	7.7	--	--	--
	--	3.4	8.9	--	--	--
20	13.3	2.9	4.3	--	--	--
21	11.4	5.5	<d.l.	--	--	--
22	10.0	--	--	<d.l.	2.3	--
23	5.3	<d.l.	<d.l.	--	--	--
24	9.1	1.9	3.1	--	--	--
25	5.9	0.6	5.7	--	--	--
26	6.9	<d.l.	<d.l.	--	--	--
27	2.7	<d.l.	d.l.	--	--	--
28	32.5	2.6[d]	4.6[d]	2.2	35.5	--
	--	--	--	2.7	10.1	--
29	6.1	<d.l.	<d.l.	--	--	--
30	6.5	<d.l.	<d.l.	--	--	--
31	5.7	<d.l.	0.6	<d.l.	<d.l.	--

APPENDIX M
(Continued)

ISOTOPIC URANIUM CONCENTRATIONS IN SOIL AND VEGETATION ON THE FMPC[a]

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[a] Data collected during RI/FS sampling described in chapters 3.0 and 4.0. Data in Table 4-7, Total Uranium Concentrations in Soil and Vegetation on the FMPC, are repeated in Appendix M for ease of comparison to separate isotopes.

[b] See map, Figure 3-2

[c] -- Not sampled at this site.

[d] 1988 samples

[e] Onion leaves

[f] Onion bulbs

[g] Moss

[h] Mint leaves

[i] Pine needles

[j] <d.l. means that all isotopes of uranium were below detection limits.

APPENDIX N

URANIUM AND FLUORIDE IN VEGETATION SAMPLES FROM 1984 TO 1986[a]

Year	WMCO Sampling Location[b]	Distance in km from FMPC[c]	Total Uranium (pCi/g)	Flouride (mg/kg)
1984				
	8	0.7	4.59	10.5
	14	0.7	6.67	19.5
	10	0.8	7.09	13.1
	13	1.0	1.09	9.1
	20	1.2	3.20	12.8
	15	1.3	0.66	11.9
	7	1.4	4.33	7.8
	18	1.5	1.78	10.4
	19	1.6	1.06	6.4
	16	1.7	0.44	9.7
	11	1.9	0.56	8.1
	12	1.9	1.24	6.3
	17	2.2	0.32	6.6
	6	2.3	1.12	8.7
	4	4.1	0.48	7.5
	5	5.3	0.33	10.2
	9	5.6	5.06	9.8
	3	6.5	0.27	9.2
	2	8.7	0.14	9.8
	1	10.5	0.09	6.7

APPENDIX N
(Continued)

URANIUM AND FLUORIDE IN VEGETATION SAMPLES
FROM 1984 TO 1986[a]

Year	WMCO Sampling Location[b]	Distance in km from FMPC[c]	Total Uranium (pCi/g)	Flouride (mg/kg)
1985				
	8	0.7	0.88	5.6
	14	0.7	1.50	5.7
	10	0.8	2.34	11.5
	26	0.8	0.38	<2.4
	9	0.9	1.57	8.4
	20	0.9	0.18	6.2
	13	1.0	1.63	6.9
	19	1.0	0.02	<2.4
	27	1.0	0.20	<2.4
	18	1.2	0.67	6.2
	15	1.3	0.37	5.9
	7	1.4	1.40	6.5
	16	1.5	0.31	3.5
	17	1.6	0.26	4.0
	11	1.9	0.65	11.1
	12	1.9	0.31	4.1
	6	2.3	0.54	6.0
	21	2.7	0.40	6.8
	28	4.0	0.26	6.5
	4	4.1	0.25	5.8
	5	5.3	0.15	3.3
	3	6.2	0.12	14.0
	22	7.0	0.05	4.7
	23	8.0	0.03	<2.4
	24	8.1	0.08	<2.4
	25	8.5	0.04	5.9
	2	8.7	0.10	5.1
	1	10.5	0.09	3.0
	29	62.8	0.25	2.5

APPENDIX N
(Continued)

URANIUM AND FLUORIDE IN VEGETATION SAMPLES
FROM 1984 TO 1986[a]

Year	WMCO Sampling Location[b]	Distance in km form FMPC[c]	Total Uranium (pCi/g)	Flouride (mg/kg)
1986	10	0.7	3.25	6.7
	13	0.7	0.40	5.2
	15	0.7	0.80	4.5
	16	0.7	2.29	7.6
	11	0.8	0.49	4.4
	14	0.8	4.29	5.7
	9	1.0	0.72	4.6
	8	1.3	0.39	5.1
	6	1.4	0.13	5.6
	20	1.4	2.11	4.7
	7	1.5	0.13	3.8
	12	1.9	0.43	6.0
	18	1.9	0.20	7.1
	17	2.3	0.31	4.8
	5	2.7	0.21	5.2
	19	4.0	0.06	4.4
	2	4.1	0.24	4.4
	3	6.2	0.09	6.2
	1	6.5	0.06	4.6
	4	8.7	0.13	5.5

[a]Plant material primarily brome grass (Bromus sp.), but other genera represented: Allium, Daucus, Hordeum, Medicago, Melilotus, Poa, Secale, and Triticum.

[b]See map in WMCO (1987b)

[c]For the purpose of this table, the center of the production area was used for distance measurements.

Source: NLO (1985), WMCO (1986, 1987b).

APPENDIX O

URANIUM CONCENTRATIONS IN FISH, GREAT MIAMI RIVER, 1984-1986[a]

Year	Sampling Point[b]	Family[c]	Number of Samples	Concentration pCi/g Minimum	Concentration pCi/g Maximum	Concentration pCi/g Average
1984						
		2	1			0.152
	1	3	2	0.132	0.181	0.155
		4	5	0.172	0.777	0.368
		6	4	0.184	0.344	0.263
		7	1			0.270
		8	1			0.185
	TOTAL		14	0.777		0.242
1984						
		2	1			0.247
	2	3	1			0.067
		4	5	0.221	0.747	0.458
		6	3	0.195	0.538	0.305
		8	1			0.185
	TOTAL		11	0.067	0.747	0.299
1984						
		2	1			0.486
	3	3	1			0.284
		4	5	0.253	0.550	0.357
		6	2	0.338	0.339	0.338
		7	1			0.221
		8	1			0.257
	TOTAL		11	0.211	0.550	0.331

APPENDIX O (continued)

URANIUM CONCENTRATIONS IN FISH, GREAT MIAMI RIVER, 1984-1986[a]

Year	Sampling Point[b]	Family[c]	Number of Samples	Concentration pCi/g Minimum	Concentration pCi/g Maximum	Concentration pCi/g Average
1985		1	9	0.067	0.286	0.095
	1	2	2	0.106	0.153	0.107
		3	4	0.089	0.128	0.100
		4	2	0.213	0.280	0.244
	TOTAL		17	0.067	0.280	0.109
1985		1	6	0.064	0.286	0.156
	2	2	6	0.086	0.153	0.118
		3	1	0.083	0.083	0.083
		4	2	0.234	0.344	0.284
		5	6	0.141	0.254	0.187
	TOTAL		21	0.064	0.344	0.156
1985		1	1	0.057	0.057	0.057
	3	2	2	0.073	0.081	0.077
		3	4	0.039	0.118	0.006
		4	9	0.060	0.173	0.104
	TOTAL		16	0.039	0.173	0.086

APPENDIX O (continued)

URANIUM CONCENTRATIONS IN FISH, GREAT MIAMI RIVER, 1984-1986[a]

Year	Sampling Point[b]	Family[c]	Number of Samples	Concentration pCi/g Minimum	Maximum	Average
1986		1	6	0.06	0.10	0.08
		2	7	0.02	0.07	0.05
	1	3	6	0.05	0.10	0.08
		4	3	0.05	0.10	0.09
		5	3	0.05	0.10	0.07
	TOTAL		25	0.02	0.10	0.07
1986		1	6	0.03	0.06	0.05
		2	5	0.04	0.07	0.05
	2	3	5	0.03	0.10	0.06
		4	3	0.05	0.10	0.10
		5	4	0.05	0.09	0.07
	TOTAL		23	0.03	0.10	0.06
1986		1	2	0.09	0.10	0.10
	3	3	16	0.04	0.20	0.07
		4	6	0.07	0.09	0.06
		5	1	0.05	0.05	0.05
	TOTAL		25	0.04	0.20	0.07

FOOTNOTES: [a] Source: NLO (1985) WMCO (1986, 1987b)

[b] Sampling locations described in WMCO (1986, 1987a)

[c] Family: 1=Cyprinidae (carp)
2=Catastomidae (carpsucker, redhorse)
3=Centrarchidae, Sciaenidae (bass, sunfish, drum)
4=Clupeidae (gizzard shad)
5=Ictaluridae (catfish)
6=Catestomidae, Cyprinidae
7=Centrarchidae
8=Percichfhyidae